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Update on the Use of Particulate Ratios to Assess Likely PM10 Attainmment Status

Systems Applications, Inc., San Rafael, CA

Prepared for

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This report describes results of statistical analyses of PM_{15}, TSP and PM_{10} data collected during 1980-82 at collocated sites in the National Inhalable Particulate Monitoring Network. Results from this report have been used to support the use of national distributions for PM_{10}/TSP ratios. Selection of a distribution of PM_{10}/TSP ratios is an inherent assumption made in order to estimate nonattainment probabilities for PM_{10} at sites collecting only TSP data.

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An Update On The Use Of Particulate Ratios To Assess Likely PM_{10} Attainment Status

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Technical Memorandum

AN UPDATE ON THE USE OF PARTICULATE RATIOS TO ASSESS LIKELY PM 10 ATTAINMENT STATUS

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INTRODUCTION

In this memorandum the results obtained by Thrall and Burton (1983a) based on 1980-1981 data are compared to results based on 1982 data and revised 1980-1981 data. To facilitate the comparison, the new results are presented in the same way as in the earlier report. In addition, illustrations in this memo are numbered to correspond to illustrations in the earlier report, e.g., Figure 5' here corresponds to Figure 5 in the earlier report. For a description of the PM-10 attainment status problem and the development of a method of solution see Pace and Frank (1982).

There are several differences between the data set analyzed here and that used previously: (1) 1982 data, including PM 10 measurements, are now available; (2) the first quarter of 1980 has been deleted from the 1980-1981 data, since a change in filters nominally scheduled for the beginning of 1980 appears not to have been implemented at a number of sites; and (3) 24-hour or annual ratios of PM 10/DS, PM 10/TSP, or DS/TSP* exceeding 1.05 have been deleted. Items 2 and 3 were suggested by EPA technical staff as a means of improving the reliability and consistency of the data used in the analysis.

DIFFERENCES IN CONCENTRATION RATIOS WHEN GROUPED BY TIME, LOCATION, OR TOTAL CONCENTRATION

24-Hour Ratios Undifferentiated by TSP Concentration

The distribution of 24-hour DS/TSP ratios over time, beginning with the second quarter of 1980 and ending with the last quarter of 1982, is shown in Figure 5'. The accompanying analysis of variance shows that differences among the average ratios for the 11 individual quarters are statistically significant.

* DS is an abbreviation for PM_{15} measured using a dichotomous sampler.

Figures 6' and 7' show the results of grouping ratios by climate and by EPA region, respectively. Group differences are somewhat more pronounced between regions (e.g., an average ratio of 0.49 for Region 10 versus 0.59 for Region 8) than between climates (0.52 for West Coast, 0.53 for arid, and 0.56 for other locations).

Figures 8,' 9,' and 10' show the results of grouping ratios by state, city, and site, respectively. In each of the figures we display the two groups whose histograms indicate the range of ratio distributions among all the groups. Note, however, that the analysis of variance in each figure refers to all groups having at least two observations, and not merely the two groups displayed. As expected, we see larger differences between cities than between states. Since there are typically only one or two sites per city in our sample, the variability of ratios between sites is similar to that between cities.

24-Hour Ratios Corresponding to High TSP Concentration

Figure 11' shows the effect of grouping ratios by TSP concentration (TSP < 150 $\mu g/m^3$ versus TSP > 150 $\mu g/m^3$). In most of the remainder of the report we restrict our attention to the latter group of ratios, corresponding to high TSP concentrations, since, as Pace and Frank point out, it is this group of observations that would most likely produce the high PM 10 concentrations of interest. Indeed, taking the TSP measurements at face value, one can argue that high PM 10 concentrations (> 150 $\mu g/m^3$) can occur only on days of high TSP concentration. We see from the results presented in Figure 11' that screening out observations corresponding to low TSP concentrations (< 150 $\mu g/m^3$) has little effect on the average and standard deviation of the ratios. Restricting attention to site-days having high TSP concentrations (> 150 $\mu g/m^3$), Figures 12' through 17' show distributional changes in 24-hour DS/TSP ratios over time and location, in parallel with Figures 5' through 10'.

Comparing Figures 5' and 12', we see that one result of screening out low TSP concentrations is that the differences among mean ratios for quarterly periods are no longer statistically significant (the quarterly averages are 0.50, 0.54, 0.56, and 0.56).

Comparing the results in Figures 6' through 10' with the corresponding results in Figures 13' through 17', we see that screening 24-hour DS/TSP ratios based on TSP concentration reduces the differences in ratios that are associated with different site locations. The analysis of variance given in Figure 13' shows that there is no statistically significant difference (at the 0.01 level) between ratios measured in different climates. Figure 14' shows that the differences between EPA regions remain statistically significant, although the differences are reduced. The differences among states, among cities, or among sites remain statistically significant, as shown by Figures 15', 16', and 17', respectively. Nevertheless, these geographical differences are less pronounced for high TSP concentration, as evidenced by the diminished F-statistics in the analysis of variance tests.

Annual Ratios Undifferentiated by TSP Concentration

Following the same format for ratios of annual average DS and TSP concentrations as for 24-hour concentrations, we see from Figure 18' that the differences between the 1980, 1981, and 1982 average ratios (0.57, 0.55, and 0.54, respectively) are not statistically significant.

The analyses of variance presented in Figures 19' through 23' show that the annual ratios are geographically more homogeneous than are the 24-hour ratios. Partitioning site-years by climate or EPA region does not reveal geographic differences in average ratios beyond what one might find for a sample drawn from a geographically homogeneous population. Only the finer partitions based on states, cities, and sites show geographic location to have a statistically significant effect on average annual ratios.

To give an indication of the range of geographic variation in the distribution of annual ratios, Figures 21', 22', and 23' contrast results for two states, cities, and sites, respectively. Figure 21' compares the ratios for the state of Washington (having an average of 0.44) with those for North Carolina (having an average of 0.63). Similarly, Figure 22' contrasts the average annual ratio for New York City (0.52, an average of 0.55 and 0.49 at two sites) with the ratio for Buffalo, New York (0.57, an average of 0.68 and 0.49 at two sites). The case of Buffalo illustrates that wide site variation can exist within one city. (Figure 22' also shows that the minimum and maximum city ratios were 0.197 and 1.020, respectively.) Finally, Figure 23' demonstrates an even wider variation between the site-specific ratios in Will County, Illinois (with an average of 0.36) and those in Rubidoux, California (with an average of 0.72).

Annual Ratios Corresponding to High TSP Concentration

Figure 24' shows the effect of grouping annual ratios into low and high annual average TSP concentrations, with low and high TSP concentrations defined as being below and above 55 $\mu g/m^3$, respectively. We see that the average and standard deviation of the ratios are lower for the high TSP concentrations (0.59 ± 0.14 versus 0.55 ± 0.11). Figures 25' through 30' show the effect of time (year) and location for annual ratios corresponding to high TSP concentration, in parallel with Figures 18' through 23', which show ratio distributions undifferentiated by TSP concentration.

In general, the result of screening out low TSP concentration has only a slight effect on annual ratios. Statistically significant differences between cities and sites remain, whereas the difference between states is marginally statistically significant. The other grouping factors--year, climate, and region--do not reveal statistically significant differences.

The Use of Grouping Factors

Screening occurrences of high ratios (greater than 1.05) from the data produces an effect similar to the one reported by Thrall and Burton (1983a) when low TSP concentrations (less than 150 $\mu g/m^3$) were excluded. The effect is to reduce the differences between geographic regions, years, and so on. This is not surprising; since the higher ratios correspond to the lower TSP concentrations, the screening out of high ratios and the exclusion of low TSP concentrations produce nearly the same set of data. As a consequence, the TSP level (low or high) no longer appears to be a statistically significant factor.

Thus the case for using group-specific distributions* of ratios to estimate the probability of PM 10 attainment status, which was not strongly supported by the previous data, has even less support in the more recent and revised data.

Of course, some group differences, e.g., between quarters, are statistically significant. Nevertheless, the case against the use of group-specific ratios, even in the face of statistically significant differences, is fairly strong: when group differences are great enough to be of practical significance, e.g., for differences between sites, the sample sizes for individual groups are too small to permit reliable estimation and application of the group-specific distribution of ratios.

Since PM 10 measurements are now available, it is possible to examine this issue in a more quantitative fashion, i.e., we could evaluate the efficacy of group-specific predictions of PM 10 measurements (or predictions of whether the PM 10 concentrations are above or below some level) using statistical cross-validation techniques. The cross-validation analysis is beyond the scope of the present effort, however.

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* By a "group-specific distribution," we mean a distribution of PM_{10}/TSP or DS/TSP ratio derived specifically from sites of a particular type (i.e., within a particular group). For example, if we only considered ratios observed in a given city, this group of ratios would be specific for that city and the distribution of values would be a group-specific distribution.

POOLING NATIONAL DATA TO ESTIMATE THE STATISTICAL DISTRIBUTION OF CONCENTRATION RATIOS

Table 5' shows the sample distribution of the 24-hour ratios of PM 10/DS, PM 10/TSP, and DS/TSP for those site-days having high TSP concentrations ($> 150\ \mu g/m^3$). Because the effect of high TSP is not statistically significant for the current data set, we include Table 5" to show the same ratios for all site-days (undifferentiated with respect to high or low TSP). Tables 7' and 7" give the corresponding distributions of annual ratios. These results may be compared to the unweighted percentiles previously reported (Tables 5 and 7 of Thrall and Burton, 1983a). Because the use of weighting factors was previously found to have little effect on the distribution, this procedure was not followed in the analysis reported here.

The recently available 24-hour PM 10 measurements allow us to examine PM 10/DS ratios that, of necessity, were previously assumed to have the constant value 0.83. Tables 5' and 5" show that the sample median (50th percentile) ratio is 0.89 for high TSP concentrations and 0.85 for overall TSP concentrations. Figures 31 and 32 display scatter diagrams of 24-hour and annual concentrations, respectively. From the information included in Figure 31a, we see that the coefficient (a) minimizing the sum of squared residuals

$$(PM\ 10 - a \cdot DS)^2$$

is 0.82. Scatter diagrams of PM 10/TSP ratios versus 0.83 times corresponding DS/TSP ratios are shown in Figures 33 and 34 for 24-hour and annual data, respectively.

On the choice of ratio distribution to be used to estimate PM 10 attainment status, our judgment is that the 24-hour PM 10/TSP ratios are sufficiently numerous to be of use for the short-term standard, but that the annual DS/TSP distribution multiplied by an appropriate factor (in the

TABLE 5'. 24-Hour high TSP (> 150 $\mu g/m^3$), all ratios ≤ 1.05, April 1, 1980 - December 31, 1982.

Ratio = PM 10/DS		Ratio 2 = PM 10/TSP		Ratio 3 = DS/TSP	
Percentage	Percentile	Percentage	Percentile	Percentage	Percentile
Minimum	0.40	Minimum	0.19	Minimum	0.16
1	0.40	1	-	1	0.18
5	0.68	5	0.30	5	0.26
10	0.73	10	0.36	10	0.36
20	0.77	20	0.40	20	0.44
30	0.83	30	0.43	30	0.48
40	0.85	40	0.46	40	0.51
50	0.89	50	0.50	50	0.55
60	0.91	60	0.51	60	0.58
70	0.93	70	0.54	70	0.61
80	0.95	80	0.55	80	0.66
90	0.98	90	0.57	90	0.71
95	1.02	95	0.58	95	0.77
99	1.04	99	0.63	99	0.88
Maximum	1.05	Maximum	0.64	Maximum	0.98
Average	0.86	Average	0.48	Average	0.54
Standard deviation	0.11	Standard deviation	0.09	Standard deviation	0.14
Number of cases	116	Number of cases	34	Number of cases	283

TABLE 5". Undifferentiated 24-hour TSP, all ratios < 1.05, April 1, 1980 - December 31, 1982.

Ratio = PM 10/DS		Ratio 2 = PM 10/TSP		Ratio 3 = DS/TSP	
Percentage	Percentile	Percentage	Percentile	Percentage	Percentile
Minimum	0.40	Minimum	0.19	Minimum	0.02
1	0.50	1	0.20	1	0.21
5	0.62	5	0.29	5	0.33
10	0.68	10	0.34	10	0.38
20	0.75	20	0.39	20	0.44
30	0.79	30	0.42	30	0.48
40	0.83	40	0.45	40	0.51
50	0.85	50	0.48	50	0.54
60	0.88	60	0.50	60	0.57
70	0.91	70	0.54	70	0.60
80	0.93	80	0.57	80	0.65
90	0.96	90	0.65	90	0.71
95	1.00	95	0.70	95	0.78
99	1.04	99	0.79	99	0.92
Maximum	1.05	Maximum	0.91	Maximum	1.05
Average	0.84	Average	0.48	Average	0.55
Standard deviation	0.11	Standard deviation	0.12	Standard deviation	0.13
Number of cases	287	Number of cases	265	Number of cases	5733

TABLE 7'. Annual high TSP (> 55 $\mu g/m^3$), all ratios < 1.05, April 1, 1980 - December 31, 1982.

Ratio = PM 10/DS		Ratio 2 = PM 10/TSP		Ratio 3 = DS/TSP	
Percentage	Percentile	Percentage	Percentile	Percentage	Percentile
Minimum	0.52	Minimum	0.25	Minimum	0.30
1	-	1	-	1	0.31
5	0.52	5	-	5	0.36
10	0.55	10	-	10	0.41
20	0.60	20	0.38	20	0.46
30	0.61	30	0.40	30	0.50
40	0.80	40	0.45	40	0.51
50	0.81	50	0.48	50	0.54
60	0.83	60	0.49	60	0.57
70	0.86	70	0.51	70	0.59
80	0.86	80	0.53	80	0.63
90	0.91	90	0.61	90	0.67
95	0.93	95	-	95	0.73
99	-	99	-	99	0.84
Maximum	0.94	Maximum	0.64	Maximum	0.90
Average	0.77	Average	0.47	Average	0.55
Standard deviation	0.14	Standard deviation	0.11	Standard deviation	0.11
Number of cases	18	Number of cases	13	Number of cases	205

TABLE 7". Undifferentiated annual TSP, all ratios < 1.05, April 1, 1980 - December 31, 1982.

Ratio = PM 10/DS		Ratio 2 = PM 10/TSP		Ratio 3 = DI/TSP	
Percentage	Percentile	Percentage	Percentile	Percentage	Percentile
Minimum	0.52	Minimum	0.25	Minimum	0.20
1	-	1	-	1	0.29
5	0.52	5	0.25	5	0.36
10	0.55	10	0.36	10	0.42
20	0.60	20	0.38	20	0.47
30	0.73	30	0.40	30	0.50
40	0.81	40	0.46	40	0.52
50	0.82	50	0.48	50	0.55
60	0.83	60	0.49	60	0.58
70	0.84	70	0.53	70	0.61
80	0.86	80	0.56	80	0.63
90	0.91	90	0.61	90	0.69
95	0.93	95	-	95	0.74
99	-	99	-	99	0.90
Maximum	0.94	Maximum	0.64	Maximum	1.02
Average	0.77	Average	0.48	Average	0.55
Standard deviation	0.13	Standard deviation	0.11	Standard deviation	0.12
Number of cases	19	Number of cases	14	Number of cases	254

range of 0.75 to 0.85, depending on the criterion used to guide the choice) should be used for the long-term standard.

DISCUSSION OF SPECIFIC ISSUES

Using the above results we address the following issues raised by EPA staff at the beginning of this updating study.

(1) What options are available to regulatory agencies in making initial PM 10 attainment determinations based on scant or indirect measures of PM 10?

The options considered to date consist of variations on the application of the methodology developed by Pace and Frank (1982). Also, see Thrall and Burton (1983b). The primary issue is the choice of ratio distribution to be used, e.g., whether to apply a national or local sample distribution.

(2) Does the use of a single national distribution, estimated from currently available data, still appear to be the most appropriate option? If not, how should this recommendation be revised?

The use of a single national distribution still appears to be more reliable than the use of local distributions, because of (i) the small numbers of observations in most localities and (ii) the difficulty of applying a geographic-specific distribution to anything other than the identical geographical unit from which it was derived.

(3) Are the TSP cutpoints of 55 $\mu g/m^3$ for annual average concentrations and 150 $\mu g/m^3$ for 24-hour average concentrations still appropriate thresholds for potential PM 10 nonattainment?

Having screened out high DS/TSP ratios (which are almost always concurrent with low TSP concentrations), the difference between the average ratios for low and high TSP concentrations is no longer statistically significant. The preferable procedure still appears to be to differentiate ratios on the basis of the TSP (denominator) concentration rather than simply screening out high ratios.

(4) Are the data provided by EMSL sufficient to reliably estimate PM 10/DS and PM 10/TSP distributions? Is the 0.83 conversion factor between DS and PM 10 still appropriate?

Sample sizes of 24-hour ratios appear to be sufficient for reliable estimation, but few annual ratios are available. The 0.83 conversion factor appears to be appropriate, although more precise criteria and probably more data would be required to estimate (with two-digit accuracy) the "best" conversion factor.

(5) Recommend a procedure to be used by regulatory agencies for initial determination of attainment of annual and 24-hour PM 10 standards. Discuss the reliability of the procedure. Provide all results necessary to the implementation of the procedure and the evaluation of its reliability. These results may include estimated distributions of DS/TSP, PM 10/TSP, and PM 10/DS as appropriate.

We recommend that the national 24-hour PM 10/TSP distribution be used to estimate 24-hour PM 10 attainment status and that attainment of the annual PM 10 standard be estimated using the national DS/TSP distribution multiplied by 0.83. For the current data, in which high ratios have been screened out, no differentiation between low and high TSP ratios is needed. These distributions are given in Tables 5" and 7". As indicated by Figures 31 and 32 these procedures should yield predicted PM 10 concentrations typically within 10 $\mu g/m^3$ of the measured concentration.

As discussed in the previous section, and by Thrall and Burton (1983b), there are further methods for gauging the reliability of these procedures.

After circulation of an initial draft of this memorandum, we received several comments from EPA reviewers to which we now respond.

(A) The exclusion of ratios greater than 1.05 causes the previously reported relationship between DS/TSP ratios and TSP concentrations to disappear. The deletion of high ratios may also induce a bias in the estimated distribution of ratios. Two alternatives to the deletion of high ratios are: (1) to eliminate from the analysis those sites tending to produce high ratios (or other anomalies) or (2) to remove extremely low ratios in addition to the removal of extremely high ratios.

The high concentrations were deleted at the request of EPA project staff since these ratios are regarded as not physically meaningful. At issue is whether we wish to use the ratios to estimate the results of PM-10 monitoring, even though monitoring results may be occasionally erroneous, or whether we wish to use the definition of PM-10, PM-15, and TSP (concentrations of particulate having aerodynamic diameters less than 10, 15, and 20 μm, respectively) to rule out ratios greater than unity. The latter course was taken at the direction of EPA staff.

The deletion of high ratios does of course alter the empirical cumulative distribution. The number of site-days or site-years in which ratios are less than a specified value, x, with x between zero and unity, is unaltered but the total number of site-days or site-years is reduced. The result is that the proportion of site-days or site-years having ratios less than x is increased. This has the effect of increasing the estimated probability that the PM-10 concentration corresponding to a given TSP concentration is below the PM-10 standard. That is, the effect of deleting high ratios is to increase (or possibly leave unaltered) the number of sites deemed to be in attainment of the PM-10 standard, and to

reduce (or possibly leave unaltered) the number of sites deemed to have failed to attain the standard.

The suggested alterations to the deletion of high ratios are worth pursuing in future work. As more PM-10 measurements become available it will be possible to compare the performance of various procedures for estimating either PM-10 concentrations or PM-10 attainment status.

(B) Please clarify the reasoning leading to your recommendation that a national distribution of ratios be used rather than separate distributions for different geographic regions. Also comment on the use of the analysis of variance to test the similarity of distributions as opposed to a Kolmogorov-Smirnov test, for example.

The use of computer program BMDP7D, entitled "Description of Groups (Strata) with Histograms and Analysis of Variance," proved to be an efficient way to make the many comparisons in which we were interested. As noted in our previous report of 4 May 1983, an analysis of variance finding that group differences are not statistically significant does not imply that the distributions are identical, since the finding pertains not to group distributions in their entirety but only to group means (and variance in the case of BNMDP7D). In general, the "significant" factors such as "site" remained significant under a more robust (but less powerful) analysis, included in BMDP7D, that used separate rather than pooled estimates of variance. As the reviewer suggests, we did conduct nonparametric (Kolmogorov-Smirnov) tests in a few instances, but these did not alter our findings. We did not use nonparametric tests more extensively because they require much more computation and programming time, and, more importantly these tests are much less powerful, particularly for the screening of approximately 100 groups with an average of about 50 observations per group.

Regarding the use of a national distribution, our judgment is that if the choice is to apply to each group of sites either a national distribution

or the distribution obtained from that group, then the national distribution appears preferable. Our preference is based on considerations of both practicality and statistical reliability. Comparing the magnitude of sampling variability to the magnitude of group differences, it appears that the use of one large-sample distribution, that admittedly represents individual sites imperfectly, will do a better job in limiting the number of PM-10 misclassifications. We fully agree, however, that this recommendation should be further examined by comparing the performance of various methods of classifying PM-10 attainment status.

(C) Why has the analysis focused on ratios of particulates as a means of assessing PM-10 attainment status rather than some other means of assessment? More specifically, the PM-10 assessments might well be improved by taking the logarithm of particulate concentrations and using log TSP as a covariate of log PM-15 or log PM-10.

EPA project staff requested that we focus our analysis on particulate ratios, since our task was to refine the work of Pace and Frank. We did examine the covariation of log DS and log TSP in previous work. These results along with those of other workers indicate that a linear model fits the log-transformed data slightly better than the untransformed data, homogeneity of variance being an important benefit of the transformation. Our work also suggests, however, that TSP cutpoints, to be used to classify the status of sites, derived from either particulate ratios or logged particulates would be much the same. Again, it would be useful to use the recently available PM-10 data to compare the rate of correct classification of these different methods.

(D) Consideration should be given to the grouping of data into the four quarters of the year, i.e., by season, rather than grouping data into the quarters spanning the period under study. Additionally, the analysis might be improved by removing sites having an insufficient number of observations during a quarter or year.

In our previous report we did find differences between DS/TSP ratios for the four quarters of the year. Using those pairs of 24-hour DS and TSP concentrations reported during 1980-1981 for which the TSP concentration exceeded 150 $\mu g/m^3$, the quarterly averages were 0.48, 0.54, 0.57, and 0.56, respectively. A similar analysis for the current data set was hampered (although still possible) by the exclusion of the first quarter of 1980. The suggestion to remove sites having an insufficient number of observations is worth pursuing in future analyses.

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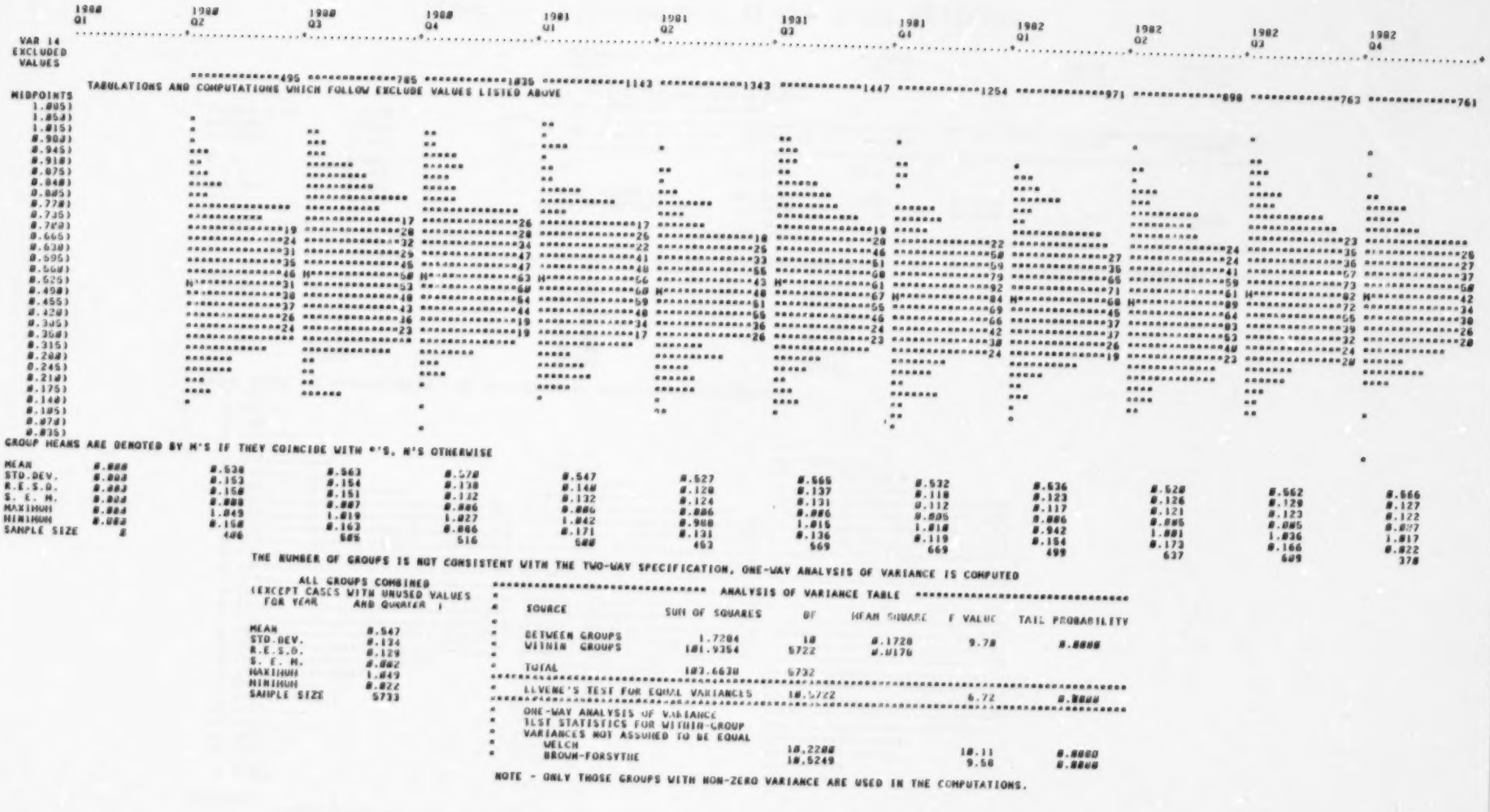

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FIGURE 5'. Distribution of 24-hour DS/TSP ratios by year (1980, 1981, 1982) and quarter.

	W.COAST	ARID	OTHER
MEAN	0.522	0.533	0.557
STD.DEV.	0.137	0.150	0.120
R.E.S.D.	0.133	0.147	0.122
S. E. M.	0.004	0.005	0.002
MAXIMUM	1.036	1.042	1.049
MINIMUM	0.131	0.150	0.022
SAMPLE SIZE	946	992	3795

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR CLIMATE)

MEAN	0.547
STD.DEV.	0.134
R.E.S.D.	0.129
S. E. M.	0.002
MAXIMUM	1.049
MINIMUM	0.022
SAMPLE SIZE	5733

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	1.1900	2	0.5950	33.27	0.0000
WITHIN GROUPS	102.4737	5730	0.0179		
TOTAL	103.6638	5732			
LEVENE'S TEST FOR EQUAL VARIANCES		2,5730		22.34	0.0000
ONE-WAY ANALYSIS OF VARIANCE					
TEST STATISTICS FOR WITHIN-GROUP					
VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		2,1742		32.02	0.0000
BROWN-FORSYTHE		2,2572		29.90	0.0000

FIGURE 6'. Distribution of 24-hour DS/TSP by climate.

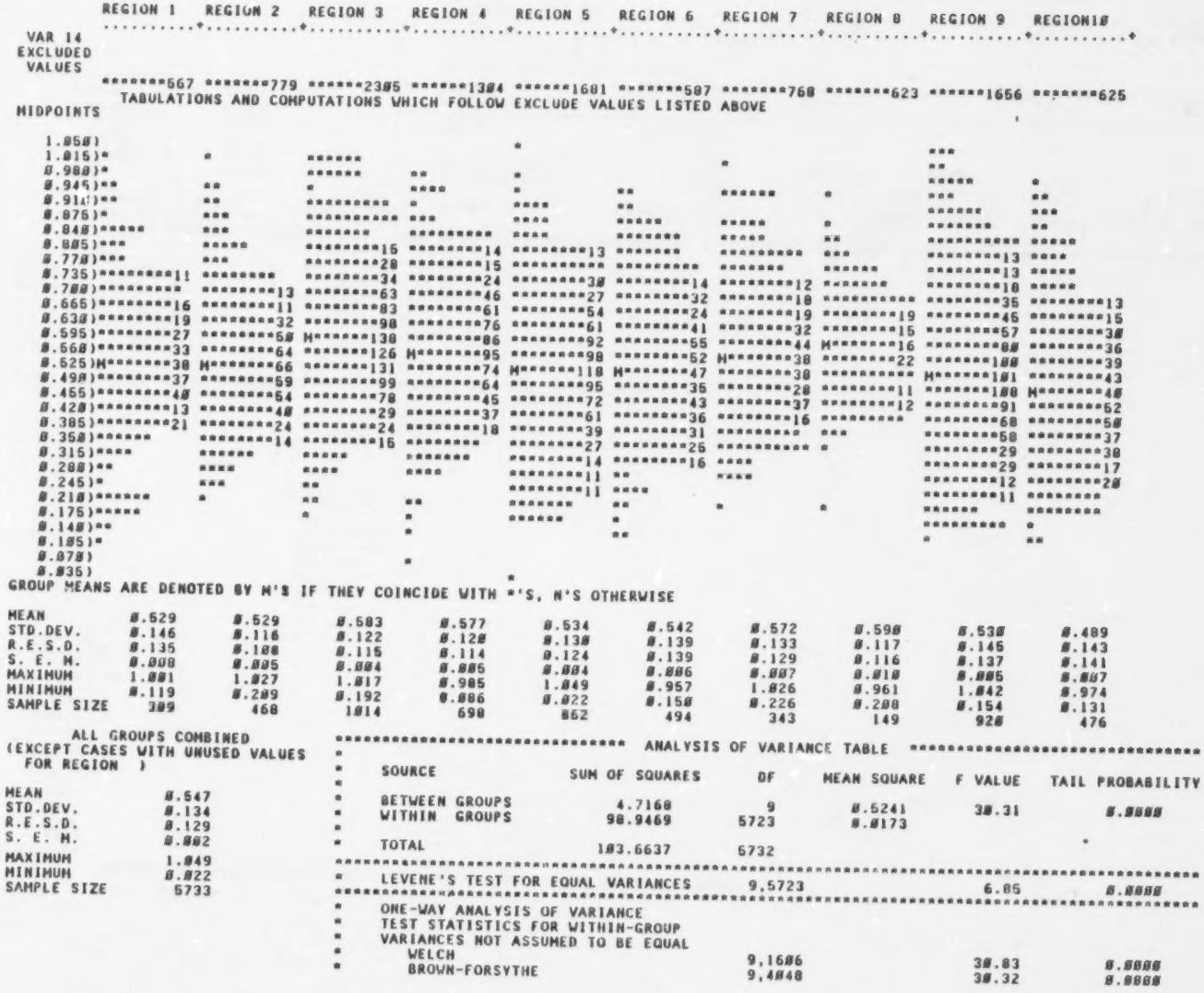

FIGURE 7'. Distribution of 24-hour DS/TSP ratios by EPA region.

```
                NE                    ID
            *..........*          *..........*
 VAR 14
EXCLUDED
 VALUES     ********185           *********43

          TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
   1.085)
   1.050)
   1.015)
   0.980)
   0.945)*
   0.910)
   0.875)
   0.840)*
   0.805)**                    **
   0.770)**
   0.735)**
   0.700)****
   0.665)M*                    *
   0.630)***                   *
   0.595)***                   ****
   0.560)****                  *****
   0.525)*                     *******
   0.490)**                    ******
   0.455)                      **
   0.420)                      M******
   0.385)                      **********
   0.350)                      *********13
   0.315)                      ******
   0.280)                      **********
   0.245)                      **
   0.210)                      **
   0.175)
   0.140)
   0.105)
   0.070)
   0.035)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN          0.660                 0.418
STD.DEV.      0.111                 0.126
R.E.S.D.      0.115                 0.120
S. E. M.      0.021                 0.014
MAXIMUM       0.942                 0.803
MINIMUM       0.502                 0.194
SAMPLE SIZE     27                    77

          ALL GROUPS COMBINED
      (EXCEPT CASES WITH UNUSED VALUES
        FOR STATE    )

      MEAN              0.547
      STD.DEV.          0.134
      R.E.S.D.          0.129
      S. E. M.          0.002
      MAXIMUM           1.049
      MINIMUM           0.022
      SAMPLE SIZE        5733

********************************* ANALYSIS OF VARIANCE TABLE *********************************
*
*     SOURCE                SUM OF SQUARES      DF      MEAN SQUARE     F VALUE    TAIL PROBABILITY
*
*     BETWEEN GROUPS            11.0502         37        0.2987         18.36          0.0000
*     WITHIN  GROUPS            92.6136       5695        0.0163
*
*     TOTAL                    103.6637       5732
*************************************************************************************************
*     LEVENE'S TEST FOR EQUAL VARIANCES      37,5695                      4.03           0.0000
*************************************************************************************************
*     ONE-WAY ANALYSIS OF VARIANCE
*     TEST STATISTICS FOR WITHIN-GROUP
*     VARIANCES NOT ASSUMED TO BE EQUAL
*        WELCH                              37, 750                     19.61          0.0000
*        BROWN-FORSYTHE                     37,1109                     18.23          0.0000

 NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.
```

FIGURE 8'. Distribution of 24-hour DS/TSP ratios by state. The states of Nebraska and Idaho are contrasted. Other states are not shown but are included in the analysis of variance.

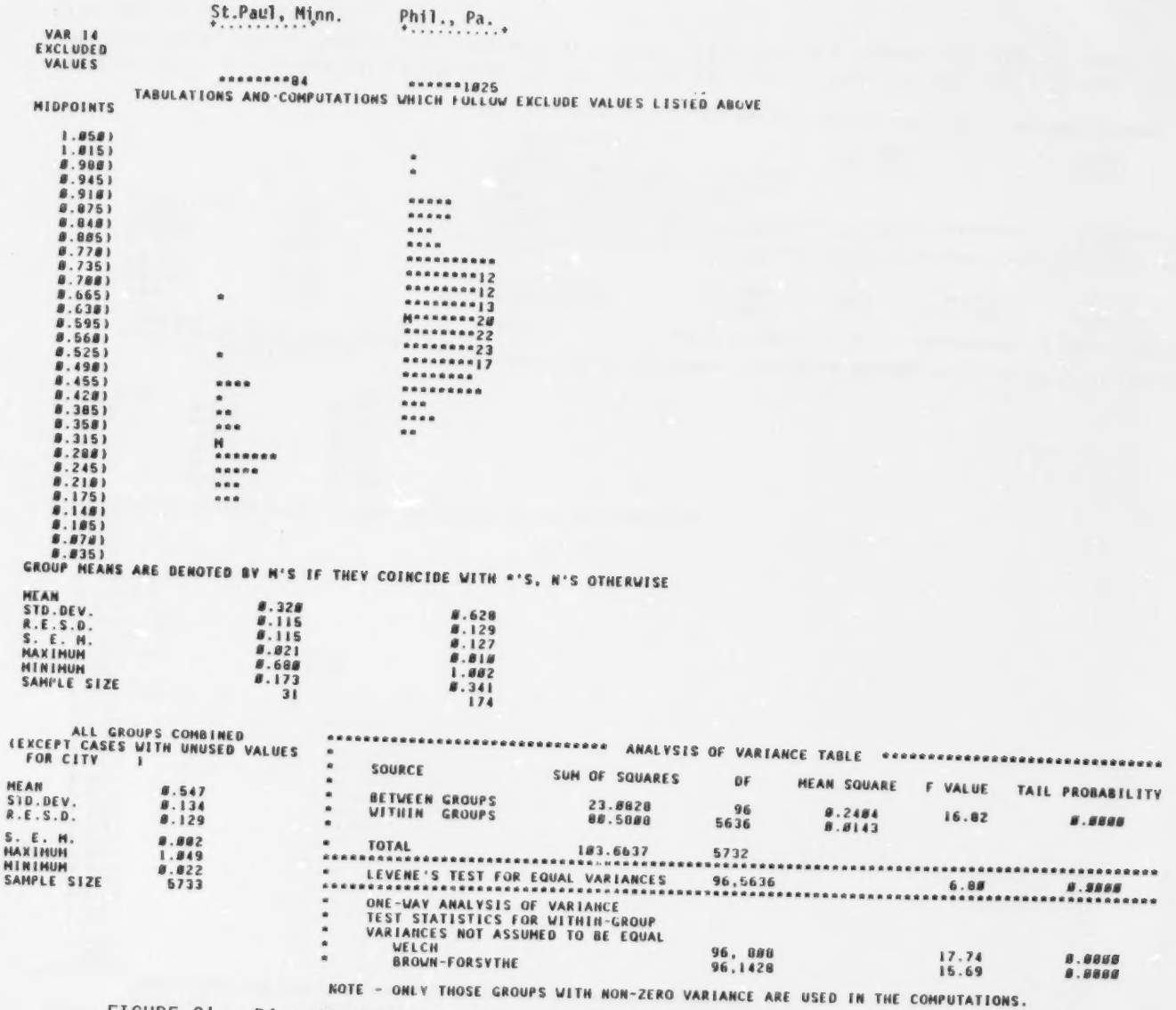

FIGURE 9'. Distribution of 24-hour DS/TSP by city. The cities of St. Paul, Minnesota (ratios obtained at one site) and Philadelphia, Pennsylvania (four sites) are contrasted. Other cities are not shown, but are included in the analysis of variance.

FIGURE 10'. Distribution of 24-hour DS/TSP ratios by site. Sites in St. Paul, Minnesota and Philadelphia, Pennsylvania are contrasted. Other sites are not shown, but are included in the analysis of variance.

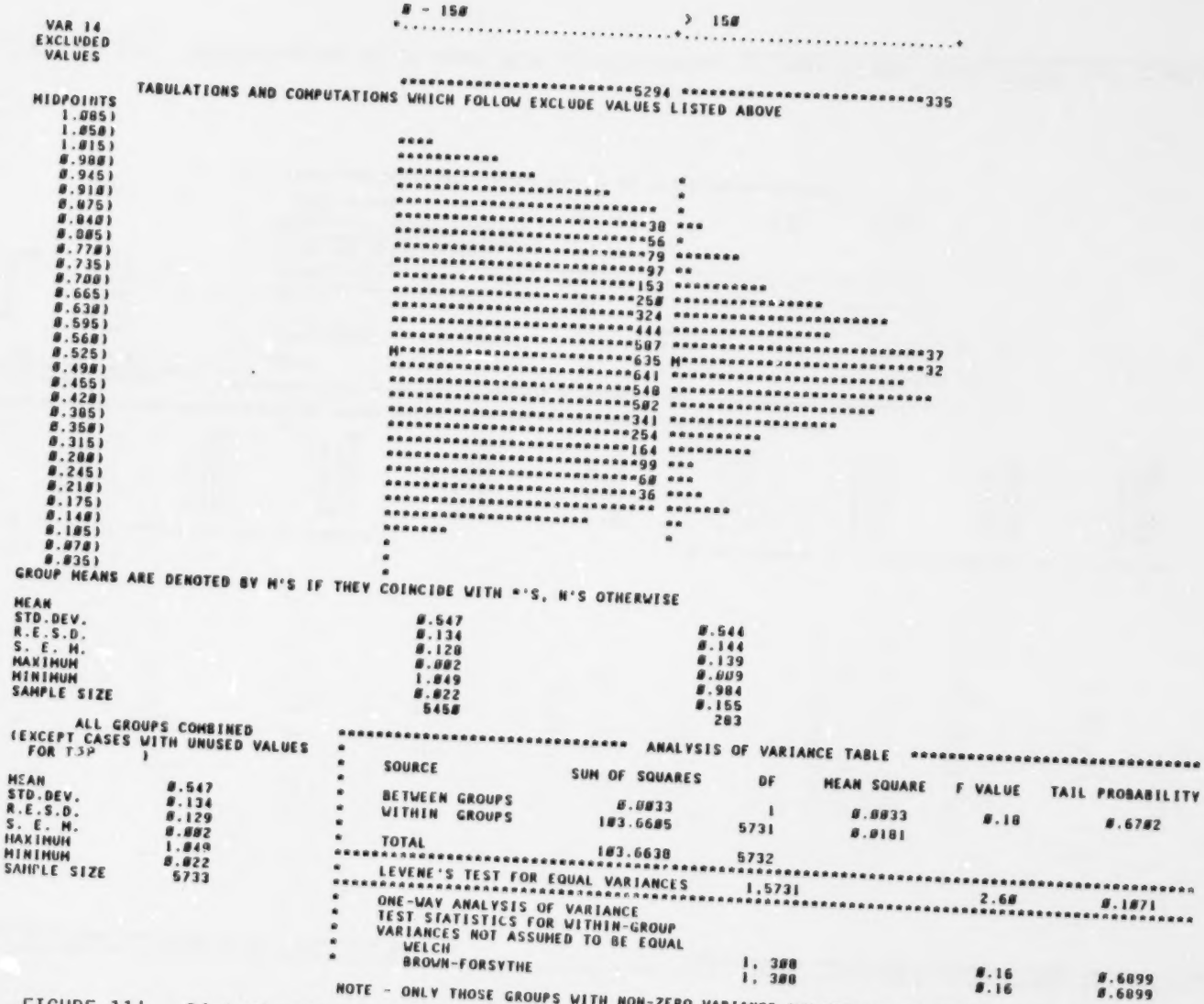

FIGURE 11'. Distribution of 24-hour DS/TSP ratios by 24-hour TSP concentration (low versus high TSP, with high TSP defined as concentrations greater than 150 $\mu g/m^3$).

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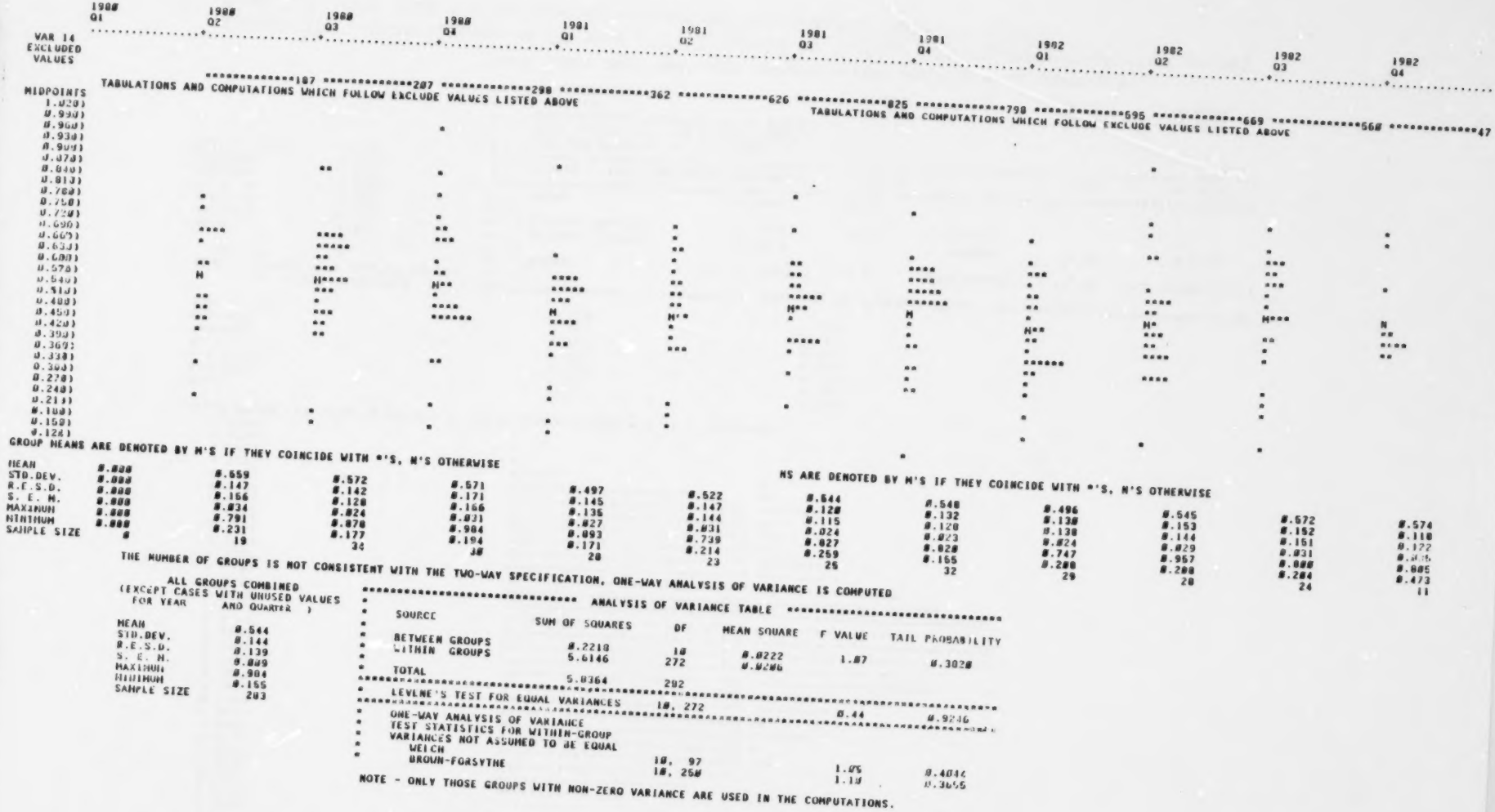

FIGURE 12'. Distribution of 24-hour DS/high-TSP ratios by year (1980, 1981, 1982) and quarter.

84003

MEAN	0.501	0.543	0.522
STD.DEV.	0.149	0.158	0.124
R.E.S.D.	0.154	0.163	0.122
S. E. M.	0.018	0.016	0.012
MAXIMUM	0.984	0.967	0.747
MINIMUM	0.214	0.171	0.155
SAMPLE SIZE	72	94	117

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR CLIMATE)

MEAN	0.544
STD.DEV.	0.144
R.E.S.D.	0.139
S. E. M.	0.009
MAXIMUM	0.984
MINIMUM	0.155
SAMPLE SIZE	283

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	0.1563	2	0.0781	3.85	0.0224
WITHIN GROUPS	5.6802	280	0.0203		
TOTAL	5.8364	282			
LEVENE'S TEST FOR EQUAL VARIANCES		2, 280		2.74	0.0661
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		2, 162		3.98	0.0205
BROWN-FORSYTHE		2, 237		3.78	0.0261

FIGURE 13'. Distribution of 24-hour DS/high-TSP ratios by climate.

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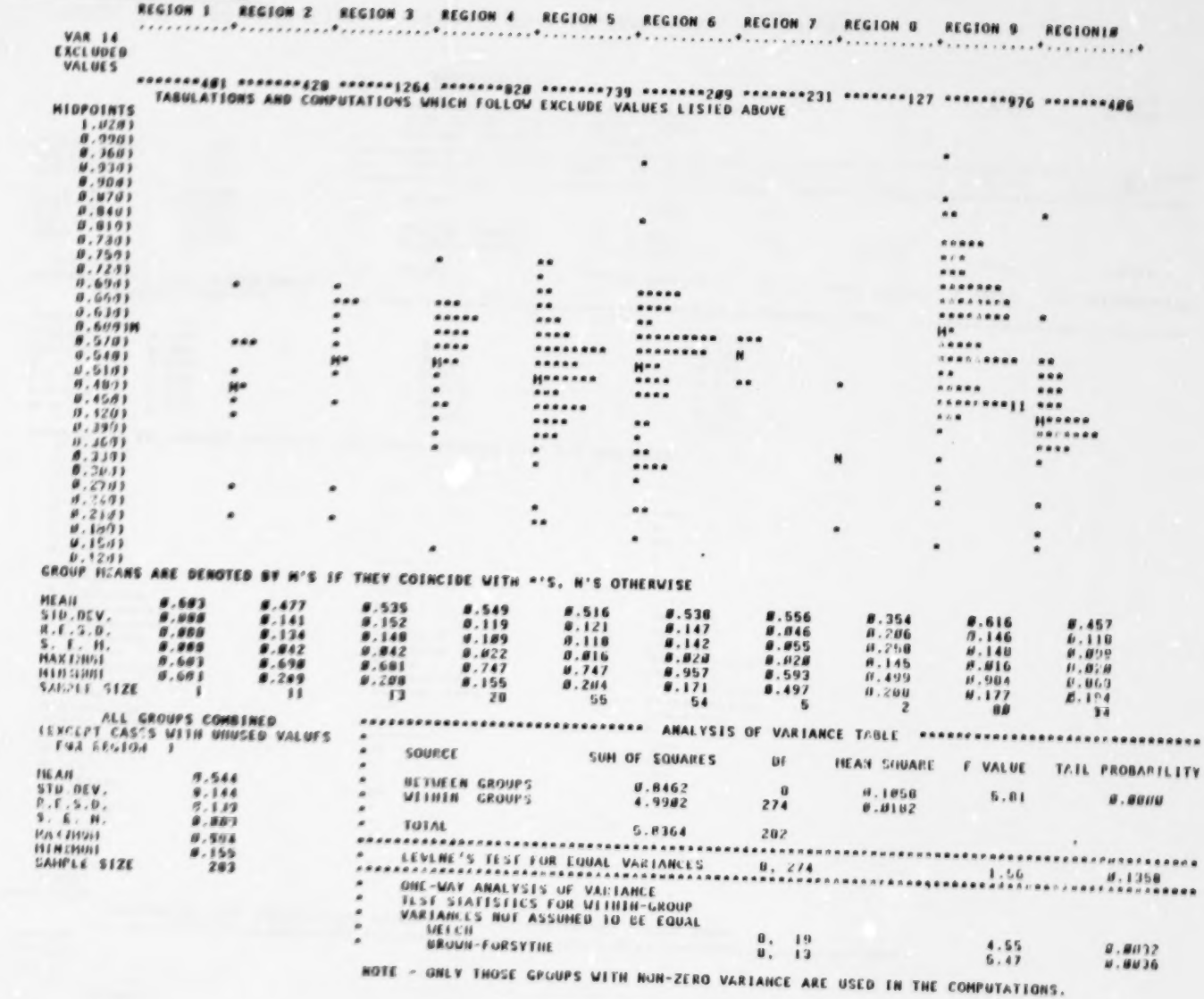
REGION 1 REGION 2 REGION 3 REGION 4 REGION 5 REGION 6 REGION 7 REGION 8 REGION 9 REGION10
VAR 14
EXCLUDED
VALUES
*******481 *******428 *******1264 *******828 *******739 *******289 *******231 *******127 *******976 *******486
TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
1.020)
0.990)
0.960)
0.930)
0.900)
0.870)
0.840)
0.810)
0.780)
0.750)
0.720)
0.690)
0.660)
0.630)
0.600)
0.570)
0.540)
0.510)
0.480)
0.450)
0.420)
0.390)
0.360)
0.330)
0.300)
0.270)
0.240)
0.210)
0.180)
0.150)
0.120)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERVISE
MEAN 0.603 0.477 0.535 0.549 0.516 0.538 0.556 0.354 0.616 0.457
STD.DEV. 0.000 0.141 0.152 0.119 0.121 0.147 0.046 0.206 0.146 0.110
R.E.S.D. 0.000 0.134 0.148 0.109 0.110 0.142 0.055 0.258 0.140 0.099
S. E. M. 0.000 0.042 0.042 0.022 0.016 0.020 0.028 0.145 0.016 0.008
MAXIMUM 0.603 0.698 0.681 0.747 0.747 0.957 0.593 0.499 0.904 0.863
MINIMUM 0.603 0.249 0.208 0.155 0.204 0.171 0.497 0.200 0.177 0.104
SAMPLE SIZE 1 11 13 28 56 54 5 2 80 34
ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR REGION)
MEAN 0.544
STD DEV. 0.144
R.E.S.D. 0.139
S. E. M. 0.007
MAXIMUM 0.904
MINIMUM 0.155
SAMPLE SIZE 283
ANALYSIS OF VARIANCE TABLE
SOURCE SUM OF SQUARES DF MEAN SQUARE F VALUE TAIL PROBABILITY
BETWEEN GROUPS 0.8462 9 0.1050 5.81 0.0000
WITHIN GROUPS 4.9902 274 0.0182
TOTAL 5.8364 282
LEVENE'S TEST FOR EQUAL VARIANCES 0, 274 1.56 0.1350
ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL
WELCH 0, 19 4.55 0.0032
BROWN-FORSYTHE 0, 13 6.47 0.0036
NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 14'. Distribution of 24-hour DS/high-TSP ratios by EPA region.

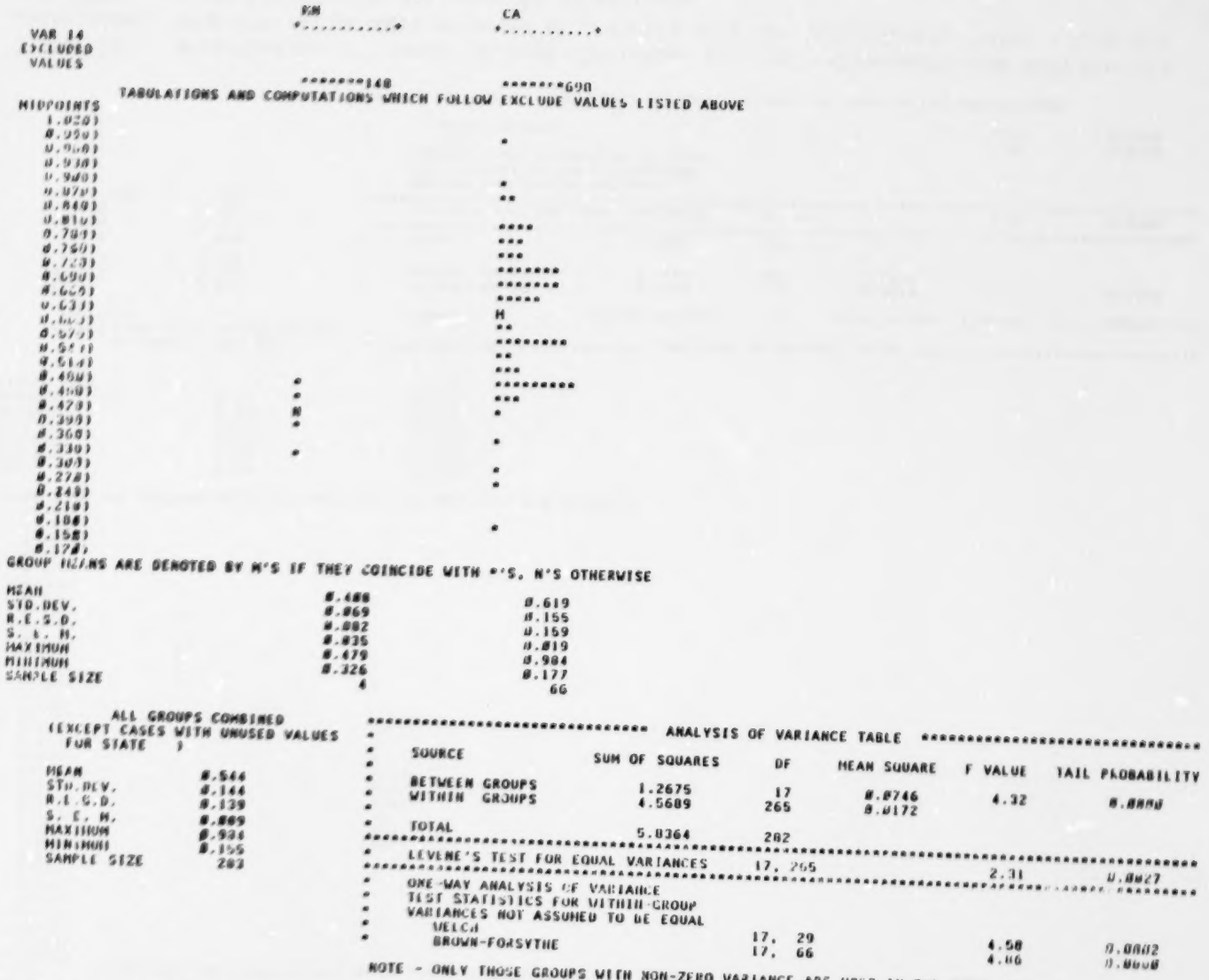
MN
CA
VAR 14
EXCLUDED
VALUES
148
690
TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
GROUP SIZINGS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE
MEAN 0.488 0.619
STD.DEV. 0.069 0.155
M.E.S.D. 0.082 0.159
S. E. M. 0.035 0.019
MAXIMUM 0.479 0.984
MINIMUM 0.326 0.177
SAMPLE SIZE 4 66
ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR STATE)
MEAN 0.544
STD.DEV. 0.144
M.E.S.D. 0.139
S. E. M. 0.009
MAXIMUM 0.984
MINIMUM 0.155
SAMPLE SIZE 283
ANALYSIS OF VARIANCE TABLE
SOURCE SUM OF SQUARES DF MEAN SQUARE F VALUE TAIL PROBABILITY
BETWEEN GROUPS 1.2675 17 0.0746 4.32 0.0000
WITHIN GROUPS 4.5689 265 0.0172
TOTAL 5.8364 282
LEVENE'S TEST FOR EQUAL VARIANCES 17, 265 2.31 0.0027
ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL
WELCH 17, 29 4.58 0.0002
BROWN-FORSYTHE 17, 66 4.46 0.0000
NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 15'. Distribution of 24-hour DS/high-TSP ratios by state. Minnesota and California are contrasted. Other states are not shown, but are included in the analysis of variance.

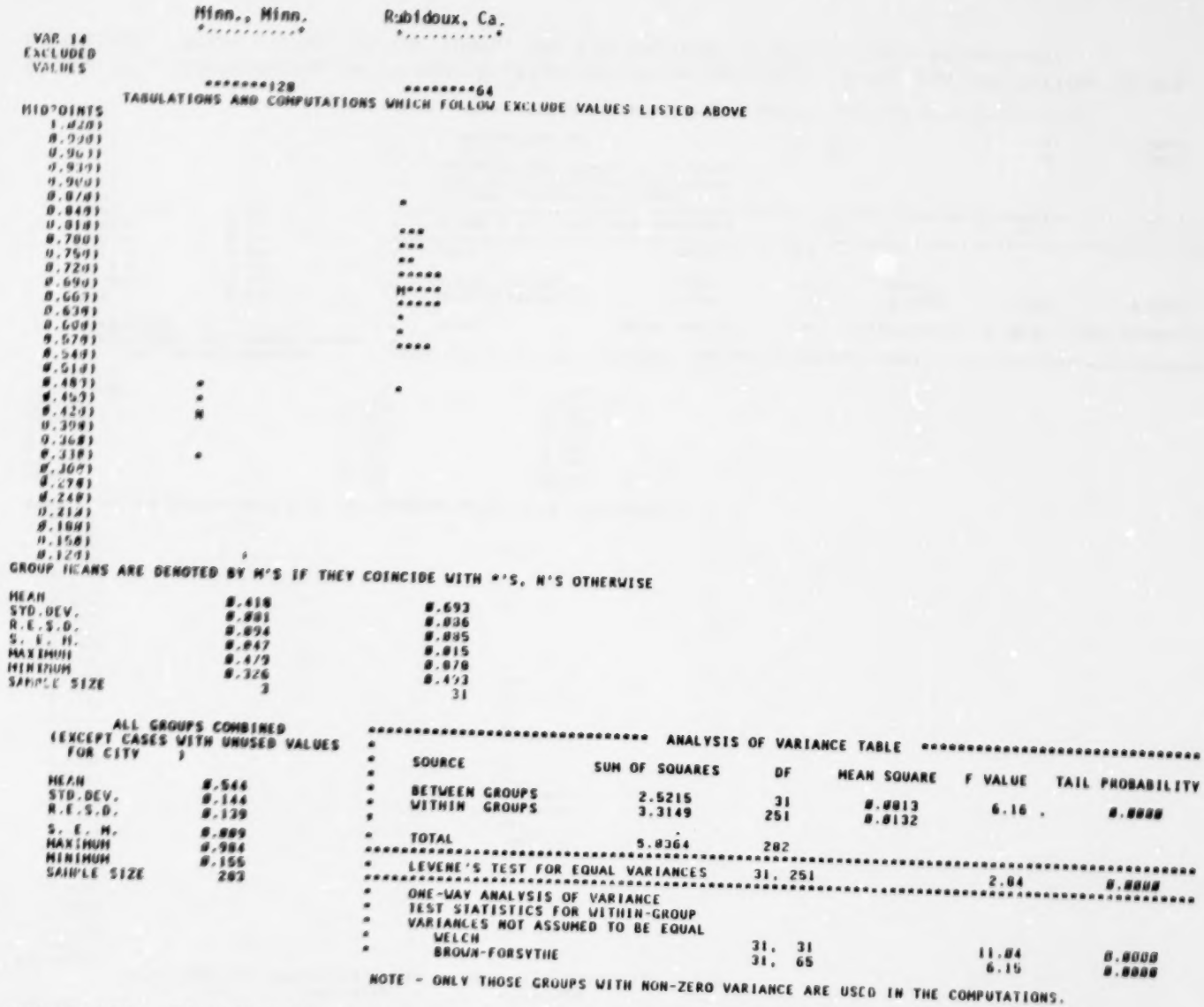

FIGURE 16'. Distribution of 24-hour DS/high-TSP ratios by city. Minneapolis and Rubidoux are contrasted. High TSP ratios were recorded at a single site for both cities. Other cities are not shown, but are included in the analysis of variance.

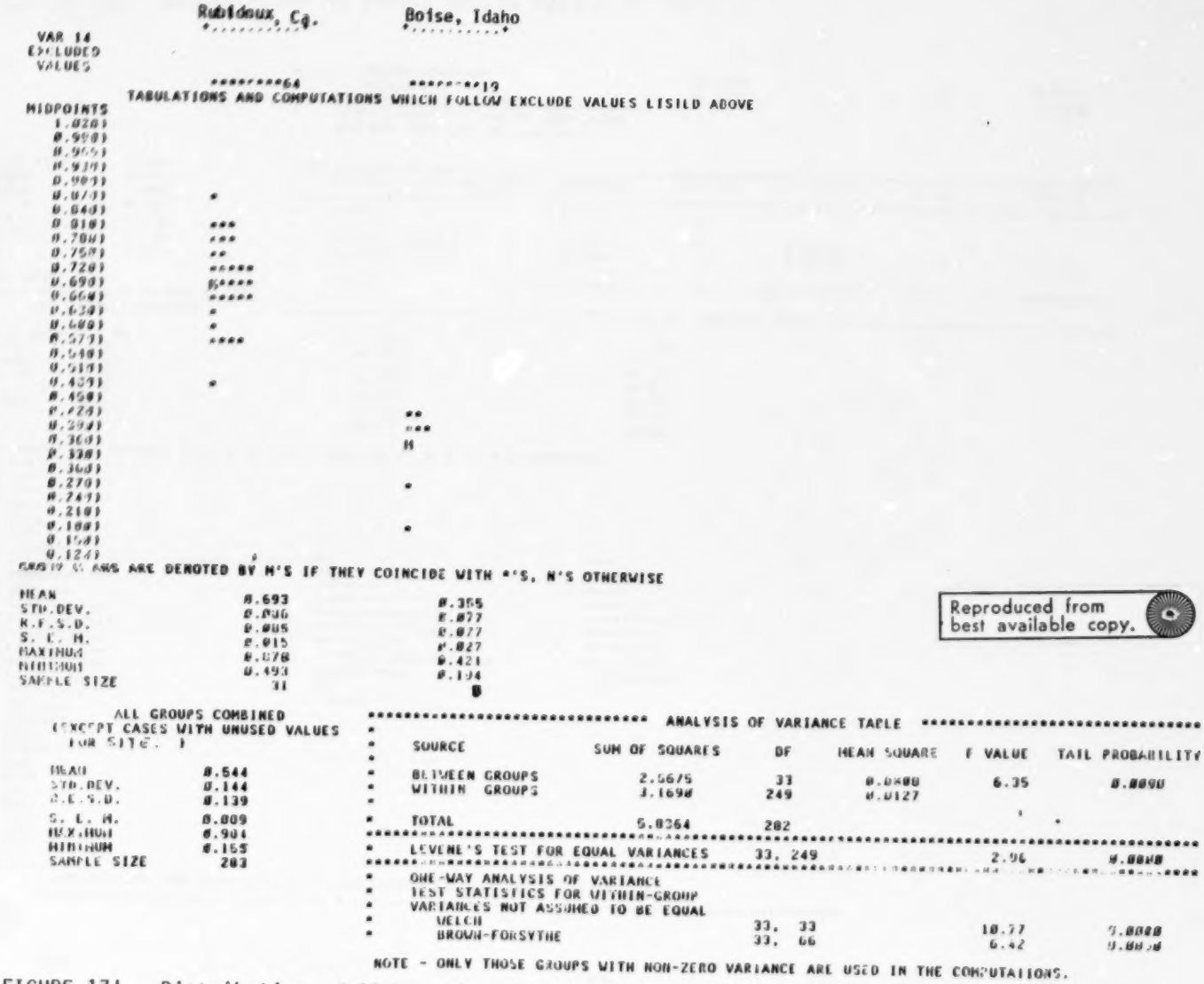
Rubidoux, Cg.
Boise, Idaho
VAR 14
EXCLUDED
VALUES
TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
GRID OF CELLS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE
MEAN 0.693 0.355
STD.DEV. 0.046 0.077
R.F.S.D. 0.065 0.077
S. E. M. 0.015 0.027
MAXIMUM 0.878 0.421
MINIMUM 0.493 0.194
SAMPLE SIZE 31 8
ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR SITE.)
MEAN 0.544
STD.DEV. 0.144
R.F.S.D. 0.139
S. E. M. 0.009
MAXIMUM 0.904
MINIMUM 0.155
SAMPLE SIZE 283
ANALYSIS OF VARIANCE TABLE
SOURCE SUM OF SQUARES DF MEAN SQUARE F VALUE TAIL PROBABILITY
BETWEEN GROUPS 2.0675 33 0.0800 6.35 0.0000
WITHIN GROUPS 3.1690 249 0.0127
TOTAL 5.0364 282
LEVENE'S TEST FOR EQUAL VARIANCES 33, 249 2.96 0.0000
ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL
WELCH 33, 33 10.77 0.0000
BROWN-FORSYTHE 33, 66 6.42 0.0000
NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

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FIGURE 17'. Distribution of 24-hour DS/high-TSP ratios by site. Sites in Rubidoux, California and Boise, Idaho are contrasted. Other sites are not shown, but are included in the analysis of variance.

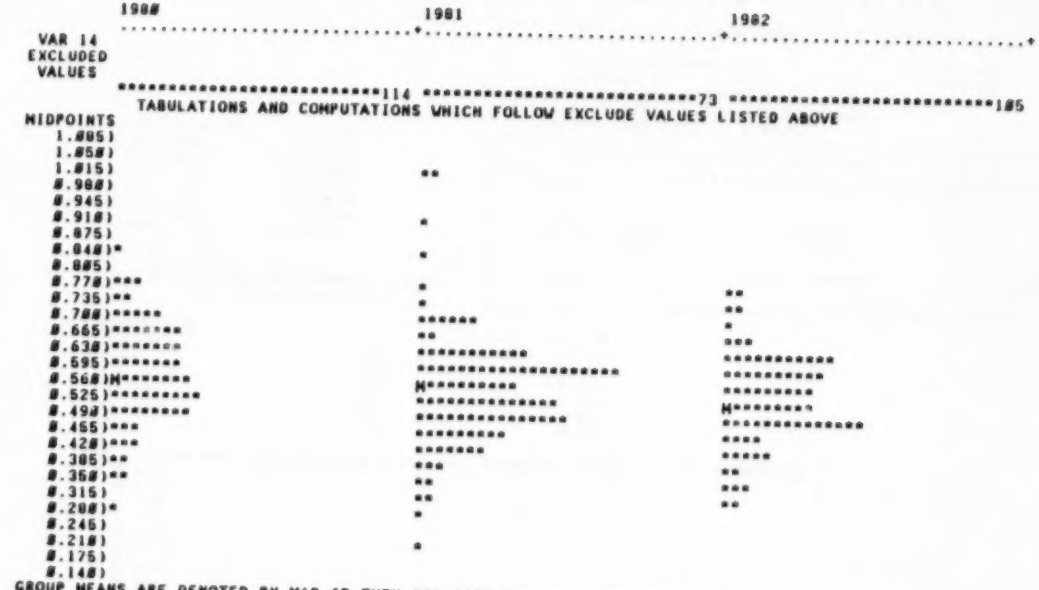
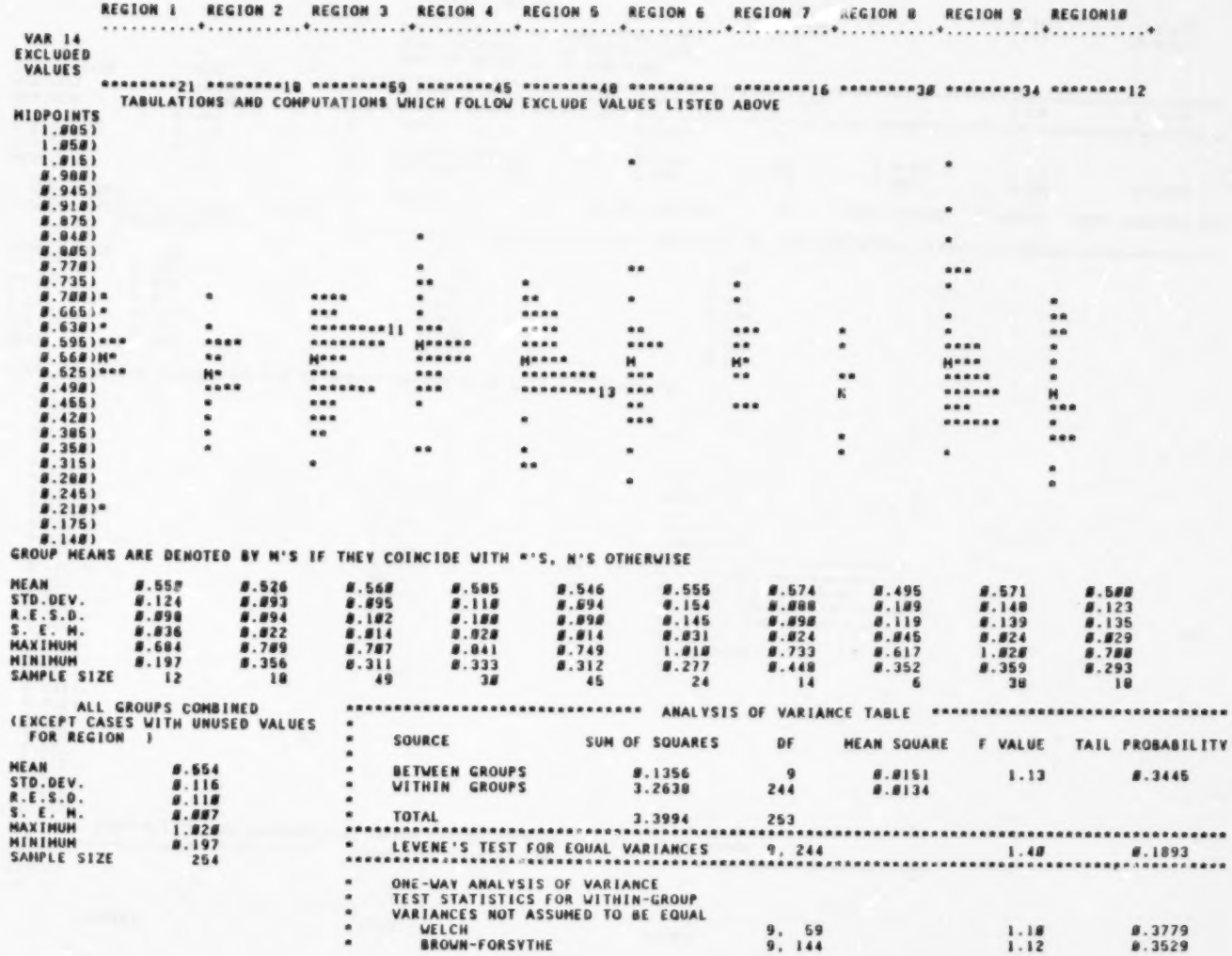


FIGURE 18'. Distribution of annual DS/TSP ratios by year.

```
                W.COAST                    ARID                    OTHER
                ...........................+...........................+...........................+
VAR 14
EXCLUDED
VALUES
                ***************************  ***************************44 ***************************223
                TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
   1.005)
   1.050)
   1.015)                                    *                           *
   0.980)
   0.945)
   0.910)*
   0.875)
   0.840)*                                                               *
   0.805)
   0.770)*                                   ****                        *
   0.735)*                                                               *
   0.700)*                                   *                           ****
   0.665)**                                  *                           **********
   0.630)***                                 ***                         *********
   0.595)***                                 *****                       ************************
   0.560)M***                                M*                          M*********************
   0.525)****                                ******                      ************************
   0.490)*****                               *****                       ***************************
   0.455)***                                 ***                         **********
   0.420)*****                               ****                        ******
   0.385)**                                  **                          ***
   0.350)                                    ***                         ****
   0.315)*                                                               ***
   0.280)*                                                               *
   0.245)                                                                *
   0.210)
   0.175)
   0.140)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN            0.545                     0.547                       0.557
STD.DEV.        0.134                     0.148                       0.106
R.E.S.D.        0.129                     0.135                       0.101
S. E. M.        0.022                     0.022                       0.008
MAXIMUM         0.896                     1.020                       1.010
MINIMUM         0.293                     0.333                       0.197
SAMPLE SIZE       30                        48                         176

      ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
  FOR CLIMATE )

MEAN            0.554
STD.DEV.        0.116
R.E.S.D.        0.110
S. E. M.        0.007
MAXIMUM         1.020
MINIMUM         0.197
SAMPLE SIZE       254

*********************************** ANALYSIS OF VARIANCE TABLE ***********************************
*
*   SOURCE                  SUM OF SQUARES      DF      MEAN SQUARE      F VALUE     TAIL PROBABILITY
*   BETWEEN GROUPS              0.0062           2          0.0031          0.23           0.7949
*   WITHIN  GROUPS              3.3932         251          0.0135
*   TOTAL                       3.3994         253
*****************************************************************************************************
*   LEVENE'S TEST FOR EQUAL VARIANCES           2, 251                      2.70           0.0648
*****************************************************************************************************
*   ONE-WAY ANALYSIS OF VARIANCE
*   TEST STATISTICS FOR WITHIN-GROUP
*   VARIANCES NOT ASSUMED TO BE EQUAL
*      WELCH                                    2,  63                     0.19           0.8287
*      BROWN-FORSYTHE                           2,  93                     0.18           0.8383
```

FIGURE 19'. Distribution of annual DS/TSP ratio by climate.



	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION10
VAR 14 EXCLUDED VALUES	21	18	59	45	48		16	30	34	12

TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE

MIDPOINTS

1.005)
1.050)
1.010)
0.900)
0.945)
0.910)
0.875)
0.840)
0.805)
0.770)
0.735)
0.700)*
0.665)*
0.630)*
0.595)***
0.560)M*
0.525)***
0.490)
0.455)
0.420)
0.385)
0.350)
0.315)
0.280)
0.245)
0.210)*
0.175)
0.140)

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	REGION 8	REGION 9	REGION10
MEAN	0.550	0.526	0.560	0.505	0.546	0.555	0.574	0.495	0.571	0.500
STD.DEV.	0.124	0.093	0.095	0.110	0.094	0.154	0.088	0.109	0.140	0.123
R.E.S.D.	0.090	0.094	0.102	0.100	0.090	0.145	0.090	0.119	0.139	0.135
S. E. M.	0.036	0.022	0.014	0.020	0.014	0.031	0.024	0.045	0.024	0.029
MAXIMUM	0.684	0.709	0.707	0.841	0.749	1.010	0.733	0.617	1.020	0.700
MINIMUM	0.197	0.356	0.311	0.333	0.312	0.277	0.448	0.352	0.359	0.293
SAMPLE SIZE	12	18	49	30	45	24	14	6	30	10

ALL GROUPS COMBINED (EXCEPT CASES WITH UNUSED VALUES FOR REGION)

MEAN	0.554
STD.DEV.	0.116
R.E.S.D.	0.110
S. E. M.	0.007
MAXIMUM	1.020
MINIMUM	0.197
SAMPLE SIZE	254

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	0.1356	9	0.0151	1.13	0.3445
WITHIN GROUPS	3.2638	244	0.0134		
TOTAL	3.3994	253			
LEVENE'S TEST FOR EQUAL VARIANCES		9, 244		1.40	0.1893
ONE-WAY ANALYSIS OF VARIANCE					
TEST STATISTICS FOR WITHIN-GROUP					
VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		9, 59		1.10	0.3779
BROWN-FORSYTHE		9, 144		1.12	0.3529

FIGURE 20'. Distribution of annual DS/TSP ratios by EPA region.

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN	0.443	0.629
STD.DEV.	0.087	0.088
R.E.S.D.	0.090	0.093
S. E. M.	0.031	0.027
MAXIMUM	0.554	0.770
MINIMUM	0.293	0.469
SAMPLE SIZE	8	11

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR STATE)

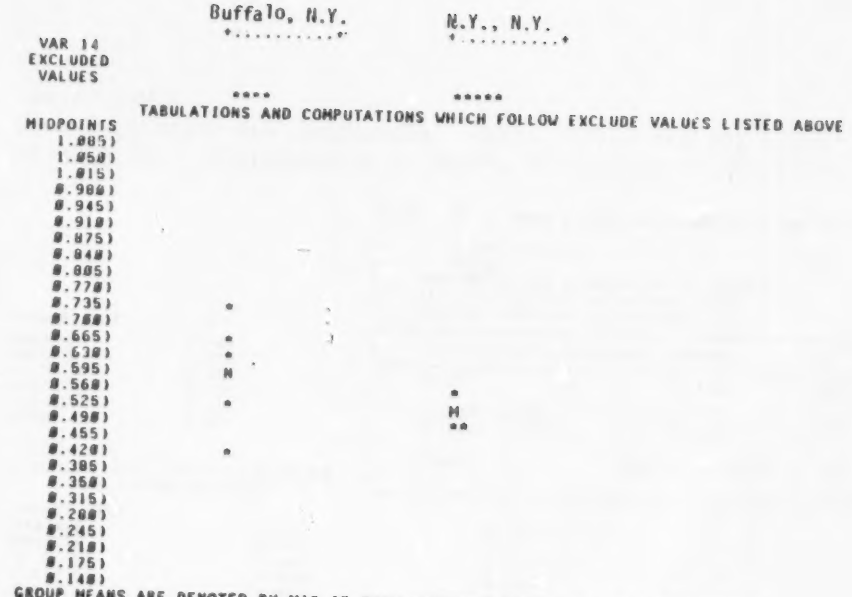
MEAN	0.554
STD.DEV.	0.116
R.E.S.D.	0.110
S. E. M.	0.007
MAXIMUM	1.020
MINIMUM	0.197
SAMPLE SIZE	254

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	0.0210	35	0.0235	1.90	0.0017
WITHIN GROUPS	2.5784	210	0.0110		
TOTAL	3.3994	253			
LEVENE'S TEST FOR EQUAL VARIANCES		35, 210		1.51	0.0488
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		35, 36		11.34	0.0000
BROWN-FORSYTHE		35, 78		2.63	0.0002

NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 21'. Distribution of annual DS/TSP ratios by state. The states of Washington and North Carolina are contrasted. Other states are not shown, but are included in the analysis of variance.



GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN	0.567	0.521
STD.DEV.	0.133	0.037
R.E.S.D.	0.149	0.044
S. E. M.	0.059	0.019
MAXIMUM	0.709	0.562
MINIMUM	0.376	0.479
SAMPLE SIZE	5	4

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR CITY 1)

MEAN	0.554
STD.DEV.	0.116
R.E.S.D.	0.110
S. E. M.	0.007
MAXIMUM	1.020
MINIMUM	0.197
SAMPLE SIZE	254

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	1.6453	79	0.0208	2.87	0.0000
WITHIN GROUPS	1.7541	174	0.0101		
TOTAL	3.3994	253			
LEVENE'S TEST FOR EQUAL VARIANCES		79, 174		5.86	0.0000
ONE-WAY ANALYSIS OF VARIANCE TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		79, 37		27.48	0.0000
BROWN-FORSYTHE		79, 13		1.64	0.1600

NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 22'. Distribution of annual DS/TSP ratios by city. Buffalo, New York and New York City, New York are contrasted. Ratios were recorded at two sites in each city. Other cities are not shown, but are included in the analysis of variance.

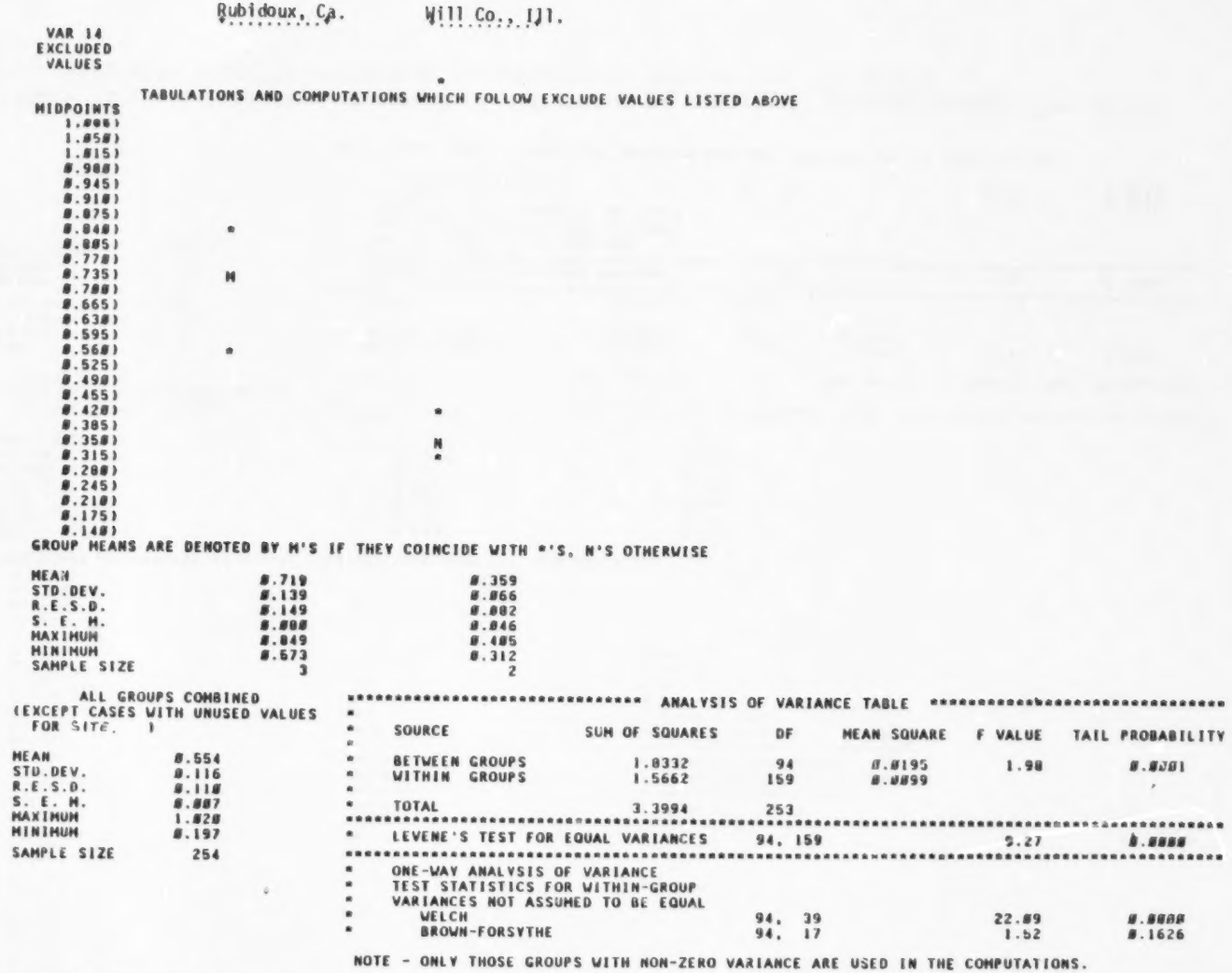
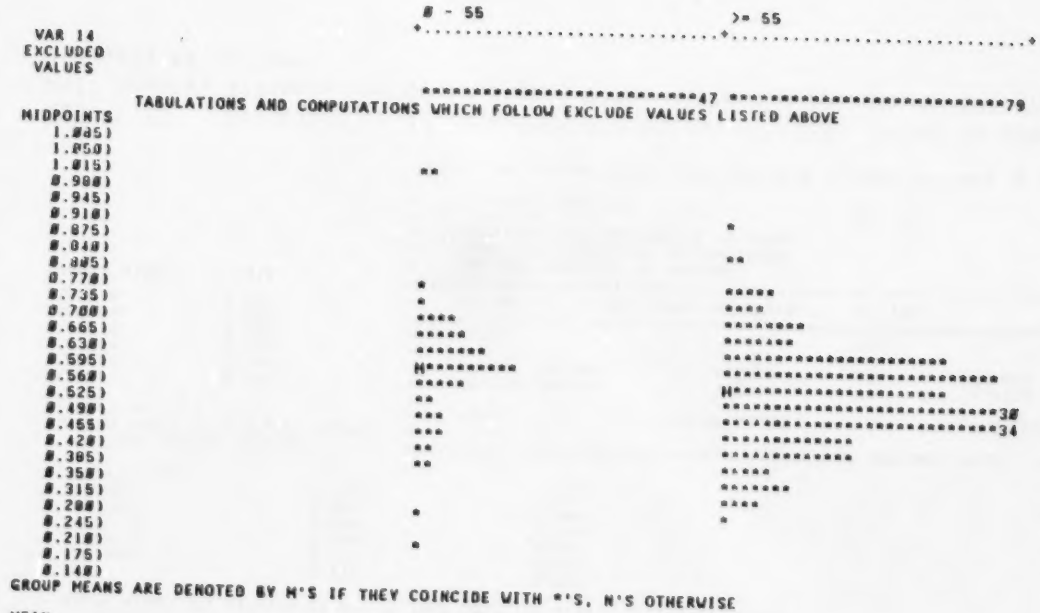


FIGURE 23'. Distribution of annual DS/TSP ratios by site. Sites in Rubidoux, California and Will County, Illinois are contrasted. Other sites are not shown, but are included in the analysis of variance.



TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN	#.587	#.546
STD.DEV.	#.144	#.1#7
R.E.S.D.	#.124	#.1#4
S. E. M.	#.#21	#.##7
MAXIMUM	1.#2#	#.896
MINIMUM	#.197	#.293
SAMPLE SIZE	49	2#5

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR MHIVOL)

MEAN	#.564
STD.DEV.	#.116
R.E.S.D.	#.11#
S. E. M.	#.#87
MAXIMUM	1.#2#
MINIMUM	#.197
SAMPLE SIZE	254

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	#.#688	1	#.#688	5.21	#.#233
WITHIN GROUPS	3.33#6	252	#.#132		
TOTAL	3.3994	253			
LEVENE'S TEST FOR EQUAL VARIANCES		1, 252		1.66	#.198#
ONE-WAY ANALYSIS OF VARIANCE					
TEST STATISTICS FOR WITHIN-GROUP VARIANCES NOT ASSUMED TO BE EQUAL					
WELCH		1, 61		3.62	#.#619
BROWN-FORSYTHE		1, 61		3.62	#.#619

NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 24'. Distribution of annual DS/TSP ratios by annual TSP concentrations (low versus high TSP, with high TSP defined as concentrations greater than 55 $\mu g/m^3$).

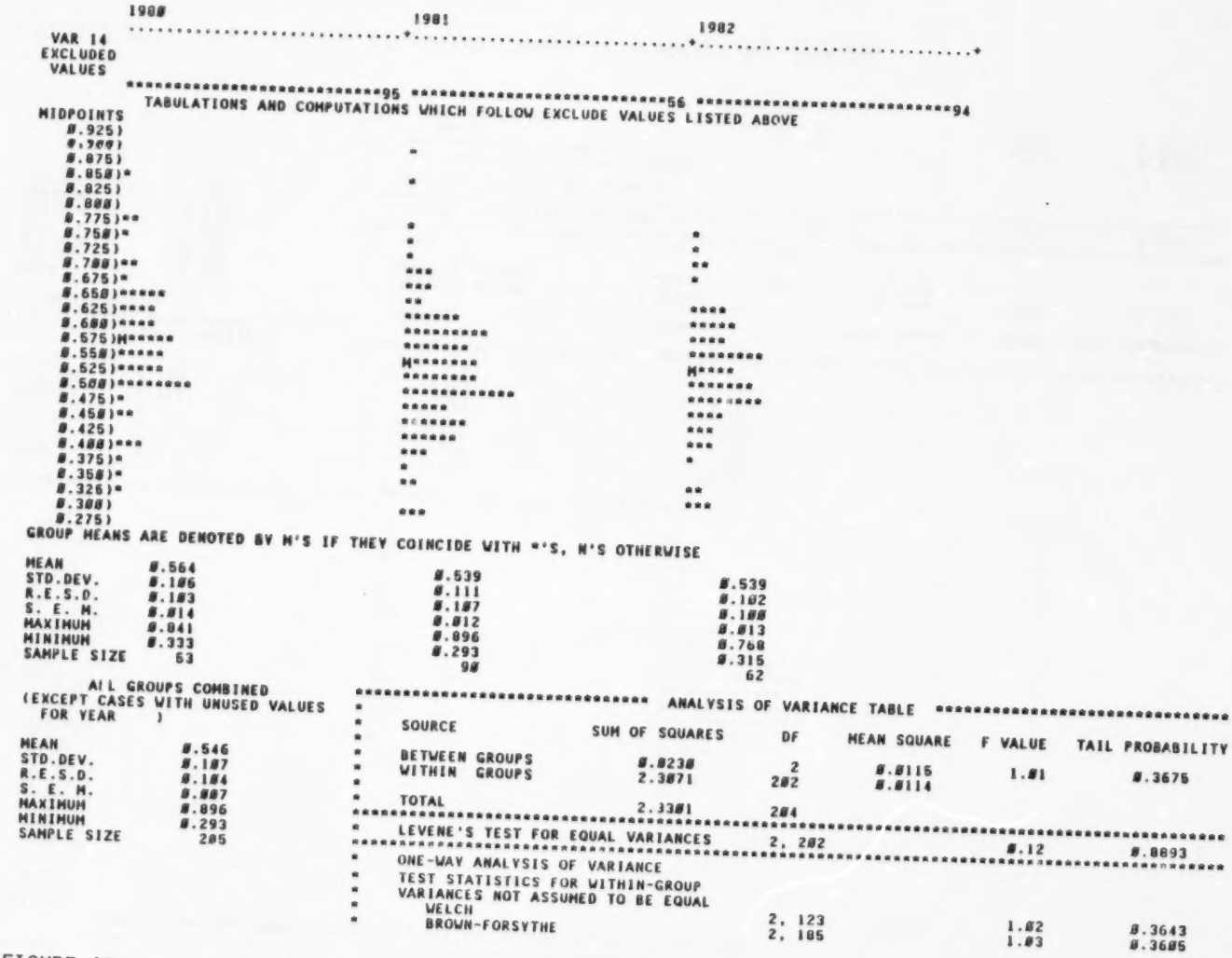


FIGURE 25'. Distribution of annual DS/high-TSP ratios by year.

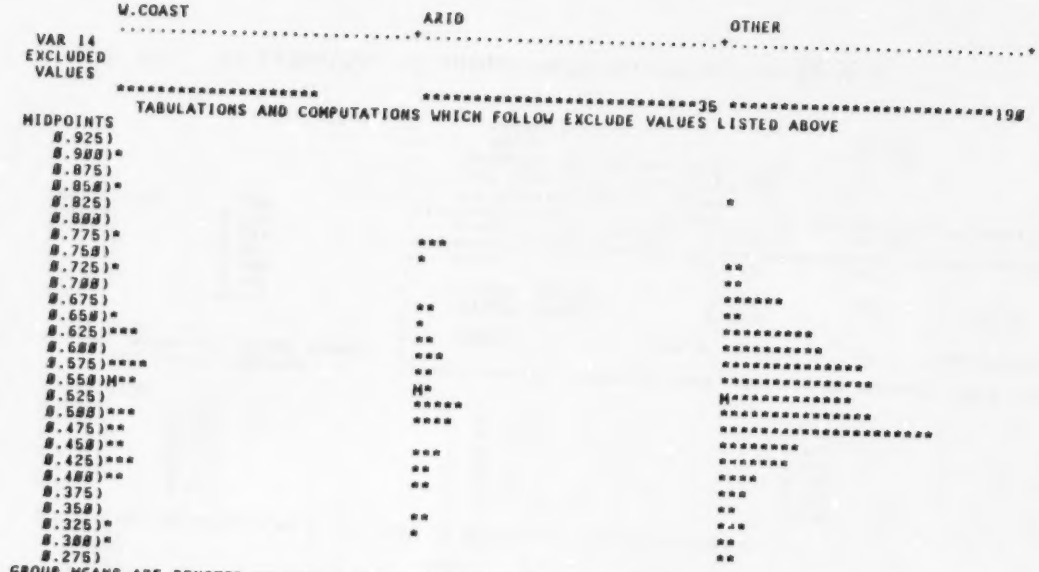
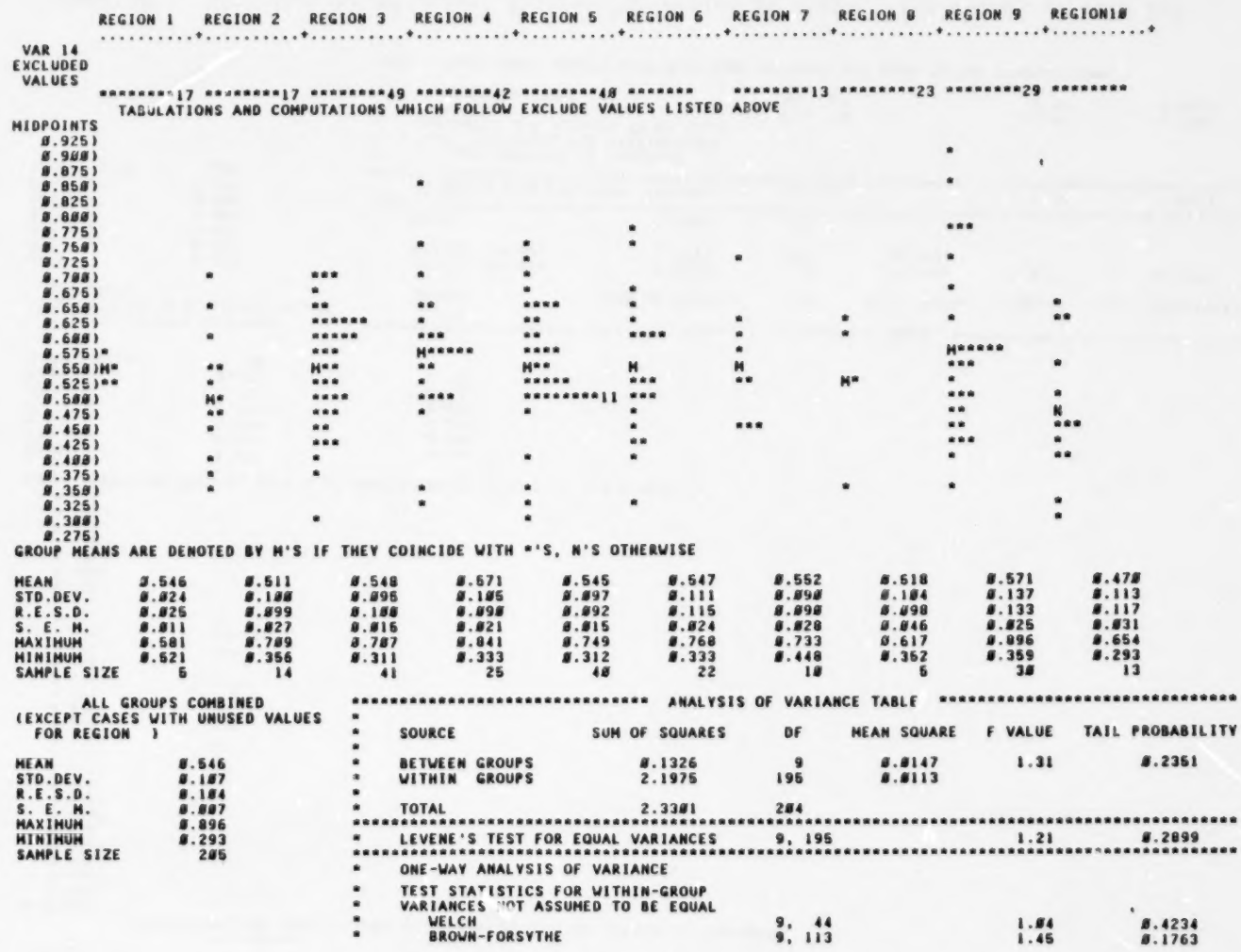


FIGURE 26'. Distribution of annual DS/high-TSP ratios by climate.



```
          REGION 1   REGION 2   REGION 3   REGION 4   REGION 5   REGION 6   REGION 7   REGION 8   REGION 9   REGION10
          ---------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
 VAR 14
EXCLUDED
 VALUES
          ********17 ********17 ********49 ********42 ********48 ********   ********13 ********23 ********29 ********
          TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
   0.925)                                                                                  *
   0.900)                                                                                  *
   0.875)                                                                                  *
   0.850)                                  *                                               *
   0.825)                                                                                  *
   0.800)                                                                                  *
   0.775)                                                  *                               ***
   0.750)                                  *               *
   0.725)                                  *                          *                    *
   0.700)          *         ***           *               *
   0.675)                    *                             *                               *
   0.650)          *         **            **              ****         *                    *                    *
   0.625)                    ******        *               **           *         *          *                    **
   0.600)          *         *****         ***             **           ****      *         *
   0.575)*                   ***           H*****          ****                   *                   H*****
   0.550)H*        **        H**           **              H**          H         H                   ***          *
   0.525)**        *         ***           *               *****        ***       **        H*        *
   0.500)          H*        ****          ****            *********11 ***                                       ***          *
   0.475)          **        ***           *               *                                          **           N
   0.450)          *         **                            *                    ***                   **           ***
   0.425)                    ***                           **                                         ***          *
   0.400)          *         *                             *            *                             *            **
   0.375)          *         *
   0.350)          *                       *               *                                  *       *
   0.325)                                  *               *            *                                          *
   0.300)                    *             *               *                                                       *
   0.275)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN          0.546      0.511      0.548      0.671      0.545      0.547      0.552      0.618      0.571      0.470
STD.DEV.      0.024      0.100      0.096      0.105      0.097      0.111      0.090      0.104      0.137      0.113
R.E.S.D.      0.025      0.099      0.100      0.090      0.092      0.115      0.090      0.090      0.133      0.117
S. E. M.      0.011      0.027      0.016      0.021      0.015      0.024      0.028      0.046      0.025      0.031
MAXIMUM       0.581      0.709      0.707      0.841      0.749      0.768      0.733      0.617      0.896      0.654
MINIMUM       0.521      0.356      0.311      0.333      0.312      0.333      0.448      0.362      0.359      0.293
SAMPLE SIZE      5         14         41         25         40         22         10          5         30         13

      ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
   FOR REGION  )

MEAN              0.546
STD.DEV.          0.107
R.E.S.D.          0.104
S. E. M.          0.007
MAXIMUM           0.896
MINIMUM           0.293
SAMPLE SIZE         205

********************************* ANALYSIS OF VARIANCE TABLE *********************************
*
*    SOURCE                 SUM OF SQUARES      DF      MEAN SQUARE    F VALUE    TAIL PROBABILITY
*
*    BETWEEN GROUPS             0.1326           9         0.0147        1.31          0.2361
*    WITHIN  GROUPS             2.1975         196         0.0113
*
*    TOTAL                      2.3301         204
**********************************************************************************************
*    LEVENE'S TEST FOR EQUAL VARIANCES       9, 195                       1.21          0.2899
**********************************************************************************************
*    ONE-WAY ANALYSIS OF VARIANCE
*    TEST STATISTICS FOR WITHIN-GROUP
*    VARIANCES NOT ASSUMED TO BE EQUAL
*       WELCH                            9,  44                        1.04          0.4234
*       BROWN-FORSYTHE                   9, 113                        1.45          0.1763
```

FIGURE 27'. Distribution of annual DS/high-TSP ratios by EPA region.

MEAN	.574	.428
STD.DEV.	.083	.088
R.E.S.D.	.089	.079
S. E. M.	.017	.030
MAXIMUM	.749	.542
MINIMUM	.481	.293
SAMPLE SIZE	23	7

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR STATE)

MEAN	.546
STD.DEV.	.107
R.E.S.D.	.104
S. E. M.	.007
MAXIMUM	.896
MINIMUM	.293
SAMPLE SIZE	206

ANALYSIS OF VARIANCE TABLE

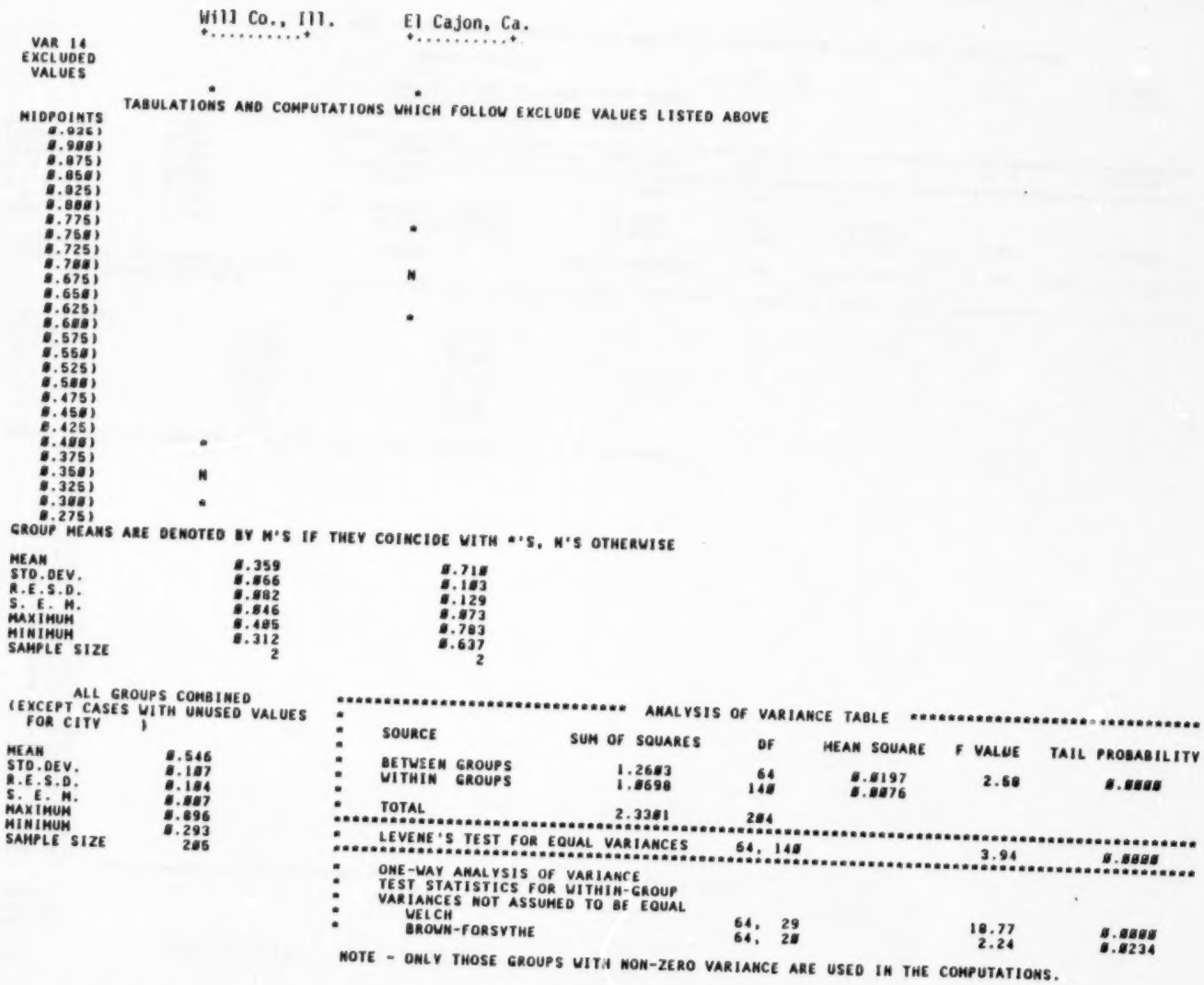
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	.5846	33	.0177	1.74	.0128
WITHIN GROUPS	1.7454	171	.0102		
TOTAL	2.3301	204			
LEVENE'S TEST FOR EQUAL VARIANCES		33, 171		1.59	.0313

ONE-WAY ANALYSIS OF VARIANCE
TEST STATISTICS FOR WITHIN-GROUP
VARIANCES NOT ASSUMED TO BE EQUAL

WELCH	33, 26	11.81	.0000
BROWN-FORSYTHE	33, 53	2.37	.0025

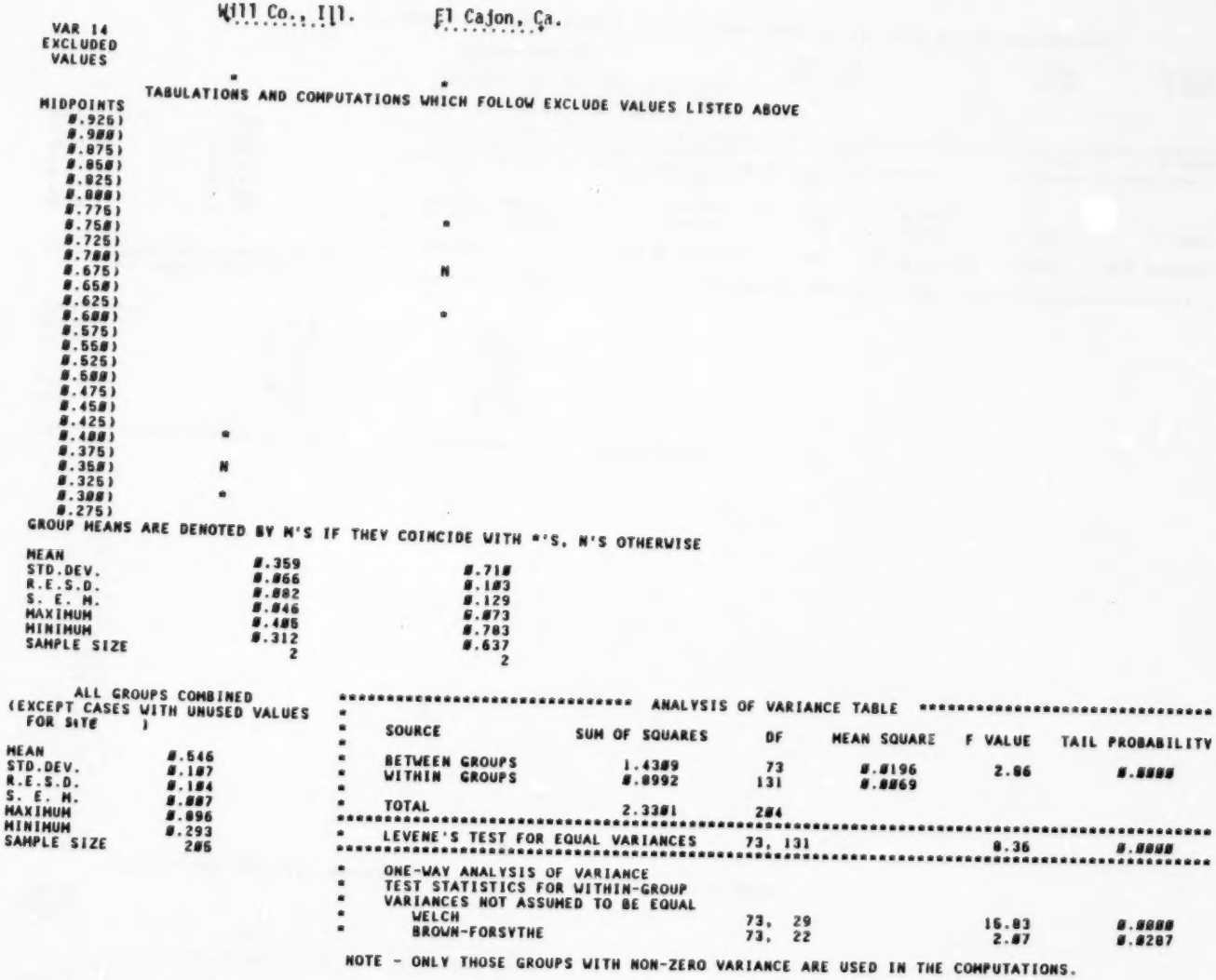
NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.

FIGURE 28'. Distribution of annual DS/high-TSP ratios by state. The states of Ohio and Washington are contrasted. Other states are not shown, but are included in the analysis of variance.



```
                    Will Co., Ill.      El Cajon, Ca.
                    +----------+        +----------+
VAR 14
EXCLUDED
VALUES

                         *                   *
          TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
   0.925)
   0.900)
   0.875)
   0.850)
   0.825)
   0.800)
   0.775)                                    *
   0.750)
   0.725)
   0.700)                                    N
   0.675)
   0.650)
   0.625)                                    *
   0.600)
   0.575)
   0.550)
   0.525)
   0.500)
   0.475)
   0.450)
   0.425)
   0.400)          *
   0.375)
   0.350)          N
   0.325)
   0.300)          *
   0.275)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE

MEAN                  0.359               0.710
STD.DEV.              0.066               0.103
R.E.S.D.              0.082               0.129
S. E. M.              0.046               0.073
MAXIMUM               0.405               0.783
MINIMUM               0.312               0.637
SAMPLE SIZE               2                   2

      ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
   FOR CITY    )

MEAN                  0.546
STD.DEV.              0.107
R.E.S.D.              0.104
S. E. M.              0.007
MAXIMUM               0.896
MINIMUM               0.293
SAMPLE SIZE             206

********************************* ANALYSIS OF VARIANCE TABLE *********************************
*
*   SOURCE                  SUM OF SQUARES      DF      MEAN SQUARE     F VALUE     TAIL PROBABILITY
*
*   BETWEEN GROUPS              1.2603          64        0.0197          2.58          0.0000
*   WITHIN  GROUPS              1.0698         140        0.0076
*
*   TOTAL                       2.3301         204
**********************************************************************************************
*   LEVENE'S TEST FOR EQUAL VARIANCES       64, 140                     3.94          0.0000
**********************************************************************************************
*   ONE-WAY ANALYSIS OF VARIANCE
*   TEST STATISTICS FOR WITHIN-GROUP
*   VARIANCES NOT ASSUMED TO BE EQUAL
*     WELCH                             64,  29                      18.77          0.0000
*     BROWN-FORSYTHE                    64,  28                       2.24          0.0234

NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.
```

FIGURE 29'. Distribution of annual DS/high-TSP ratios by city. Will County, Illinois and El Cajon, California are contrasted. High-TSP ratios were recorded at one site in each city.



```
                    Will Co., Ill.        El Cajon, Ca.
VAR 14
EXCLUDED
VALUES

                        *                     *
MIDPOINTS   TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
  0.925)
  0.900)
  0.875)
  0.850)
  0.825)
  0.800)
  0.775)
  0.750)                                      *
  0.725)
  0.700)
  0.675)                                      N
  0.650)
  0.625)
  0.600)                                      *
  0.575)
  0.550)
  0.525)
  0.500)
  0.475)
  0.450)
  0.425)
  0.400)          *
  0.375)
  0.350)          N
  0.325)
  0.300)          *
  0.275)
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN                  0.359                 0.718
STD.DEV.              0.066                 0.103
R.E.S.D.              0.082                 0.129
S. E. M.              0.046                 0.073
MAXIMUM               0.405                 0.783
MINIMUM               0.312                 0.637
SAMPLE SIZE               2                     2

        ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
   FOR SITE    )

MEAN                  0.546
STD.DEV.              0.107
R.E.S.D.              0.104
S. E. M.              0.007
MAXIMUM               0.896
MINIMUM               0.293
SAMPLE SIZE             206

********************************* ANALYSIS OF VARIANCE TABLE *********************************
*
*   SOURCE                  SUM OF SQUARES      DF      MEAN SQUARE     F VALUE    TAIL PROBABILITY
*
*   BETWEEN GROUPS              1.4389          73        0.0196          2.86          0.0000
*   WITHIN  GROUPS              0.0992         131        0.0069
*
*   TOTAL                       2.3381         204
**********************************************************************************************
*   LEVENE'S TEST FOR EQUAL VARIANCES       73, 131                       8.36          0.0000
**********************************************************************************************
*   ONE-WAY ANALYSIS OF VARIANCE
*   TEST STATISTICS FOR WITHIN-GROUP
*   VARIANCES NOT ASSUMED TO BE EQUAL
*      WELCH                            73,  29                         16.03          0.0000
*      BROWN-FORSYTHE                   73,  22                          2.07          0.0287

 NOTE - ONLY THOSE GROUPS WITH NON-ZERO VARIANCE ARE USED IN THE COMPUTATIONS.
```

FIGURE 30'. Distribution of annual DS/high-TSP ratios by site. Sites in Will County, Illinois and El Cajon, California are contrasted. Other sites are not shown but are included in the analysis of variance.

N= 297
COR= .9647

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	54.268	32.669	X= 1.1584*Y+ 2.2429	74.319
Y	44.032	27.158	Y= .80194*X+ 1.3123	51.359

ZERO INTERCEPT REGRESSION LINE
Y = 0.81971*X

RES.MS.
51.6382

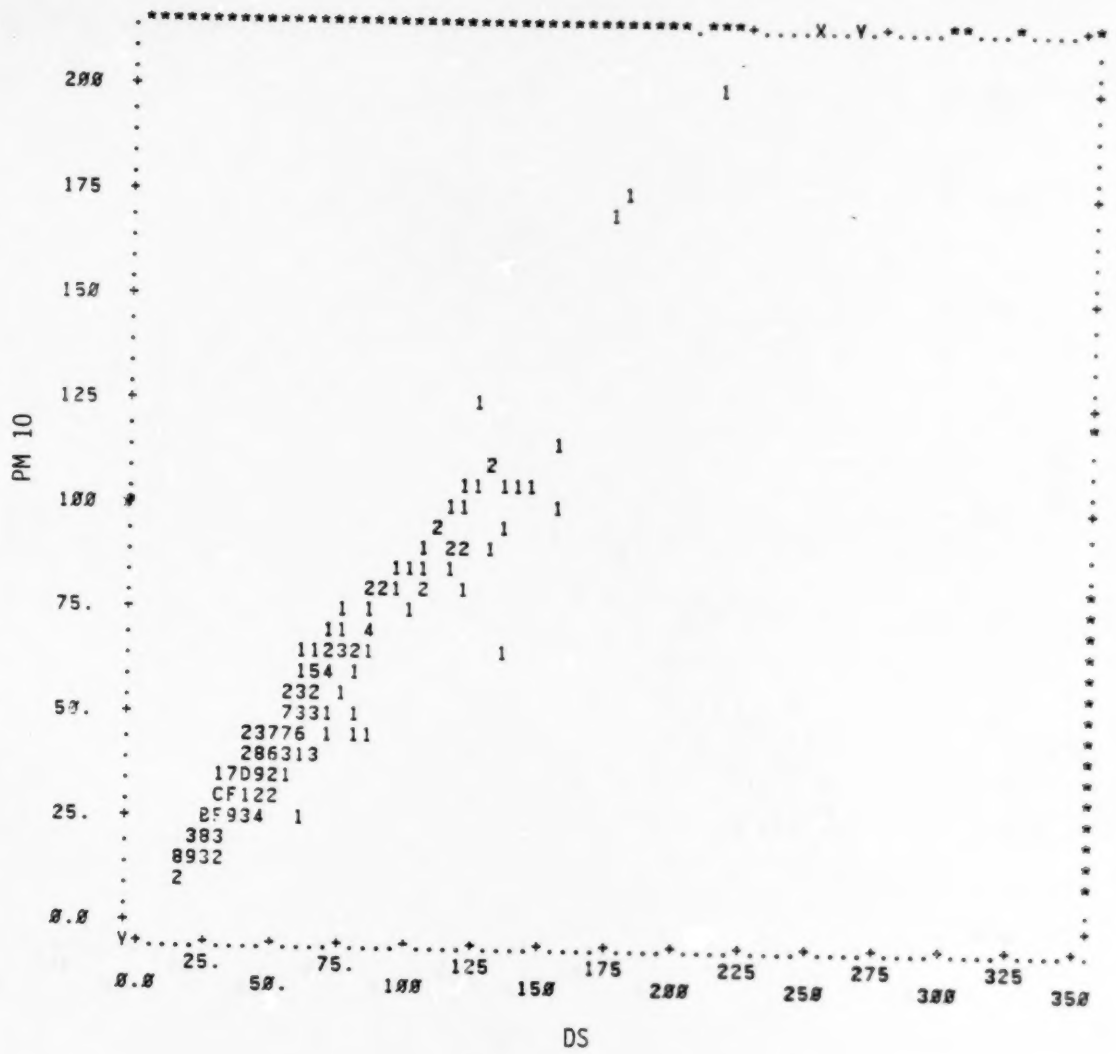


FIGURE 31a. Regression analyses for 24-hour concentrations: PM 10 versus DS.

84003

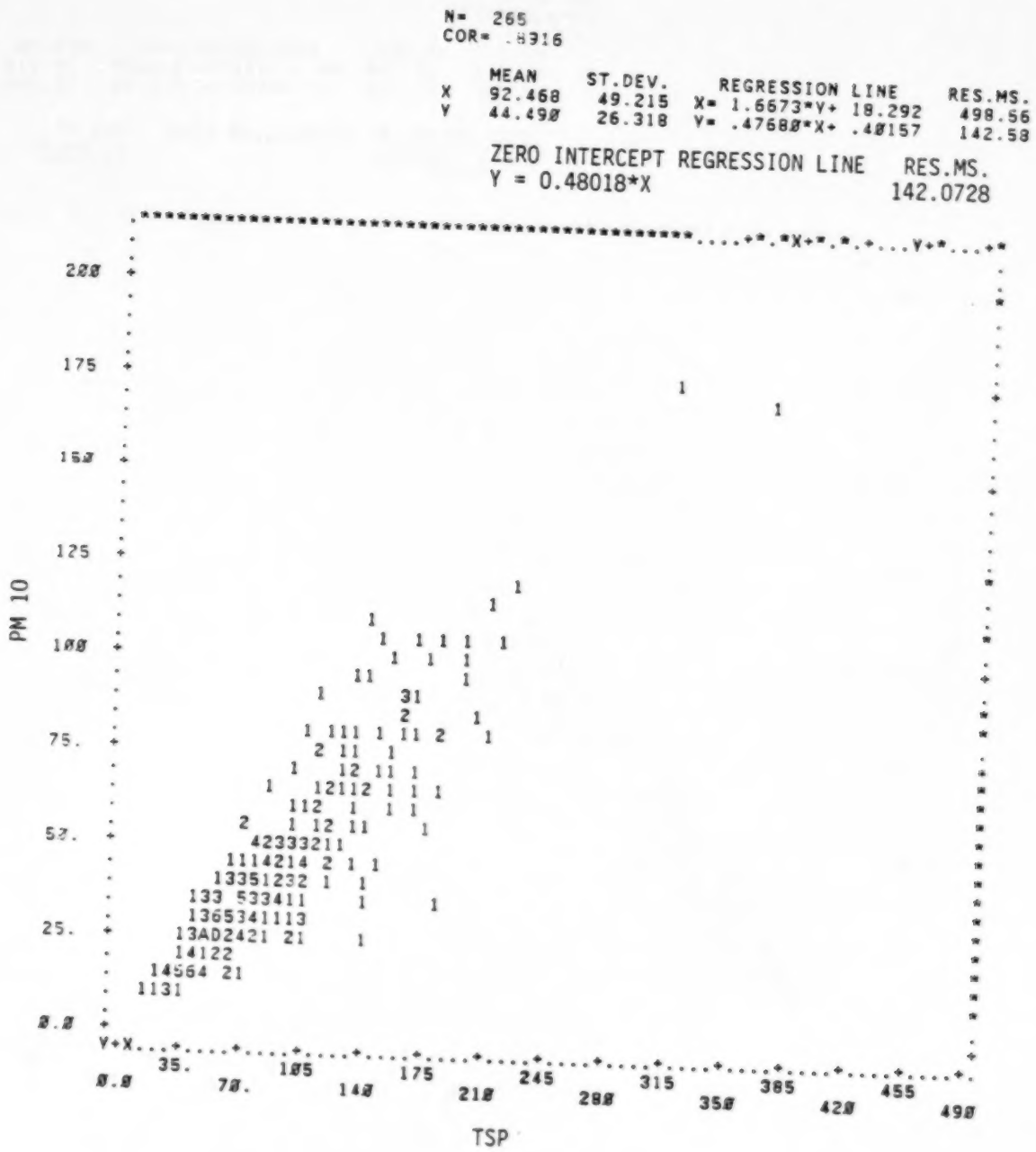


FIGURE 31b. PM 10 versus TSP.

N= 5733
COR= .8646

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	72.696	39.553	X= 1.4453*Y+ 15.036	340.60
Y	39.894	24.213	Y= .54136*X+ .53966	127.57

ZERO INTERCEPT REGRESSION LINE RES.MS.
Y = 0.54709*X 127.6199

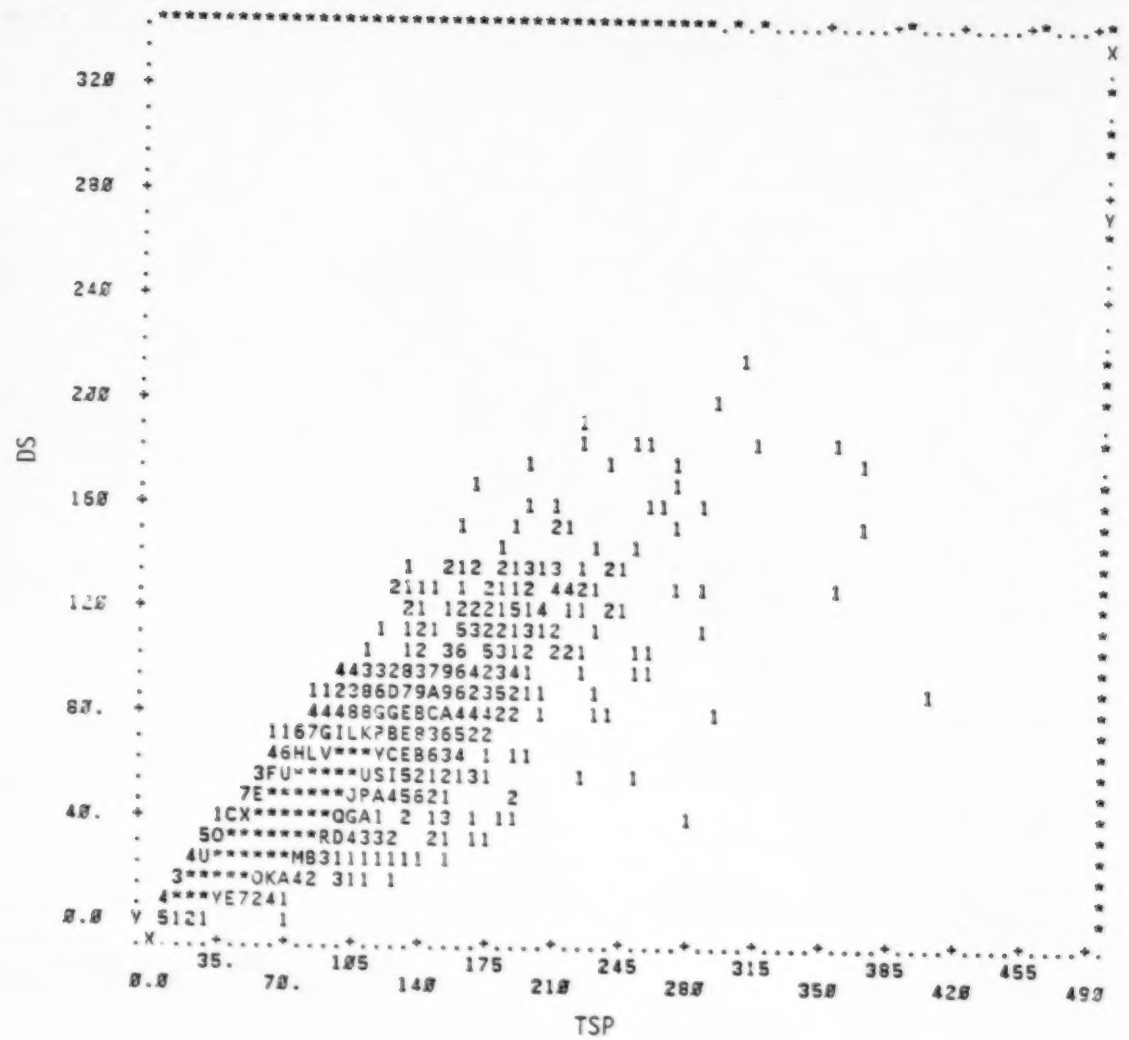


FIGURE 31c. DS versus TSP.

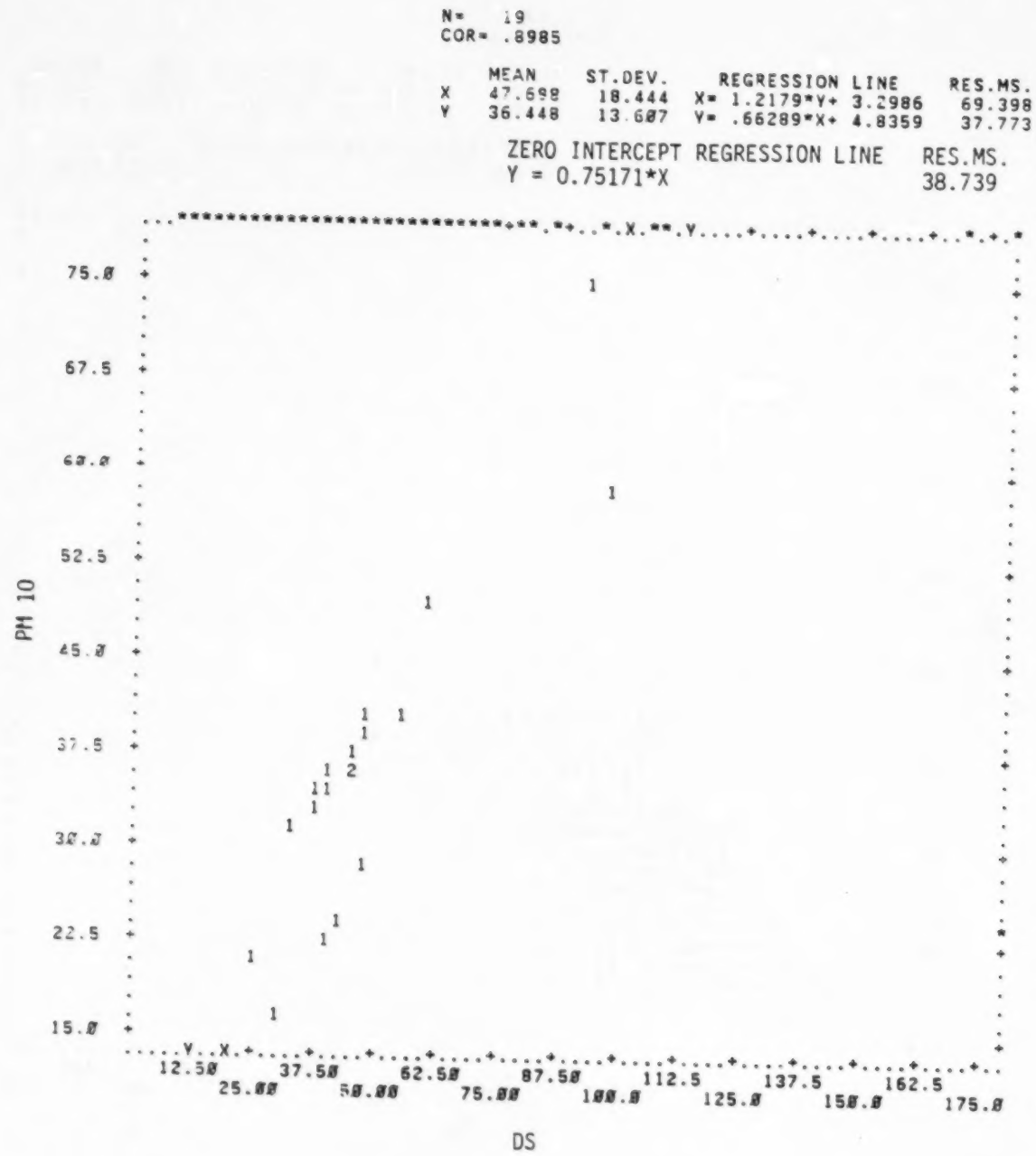


FIGURE 32a. Regression analysis for annual concentrations: PM 10 versus DS.

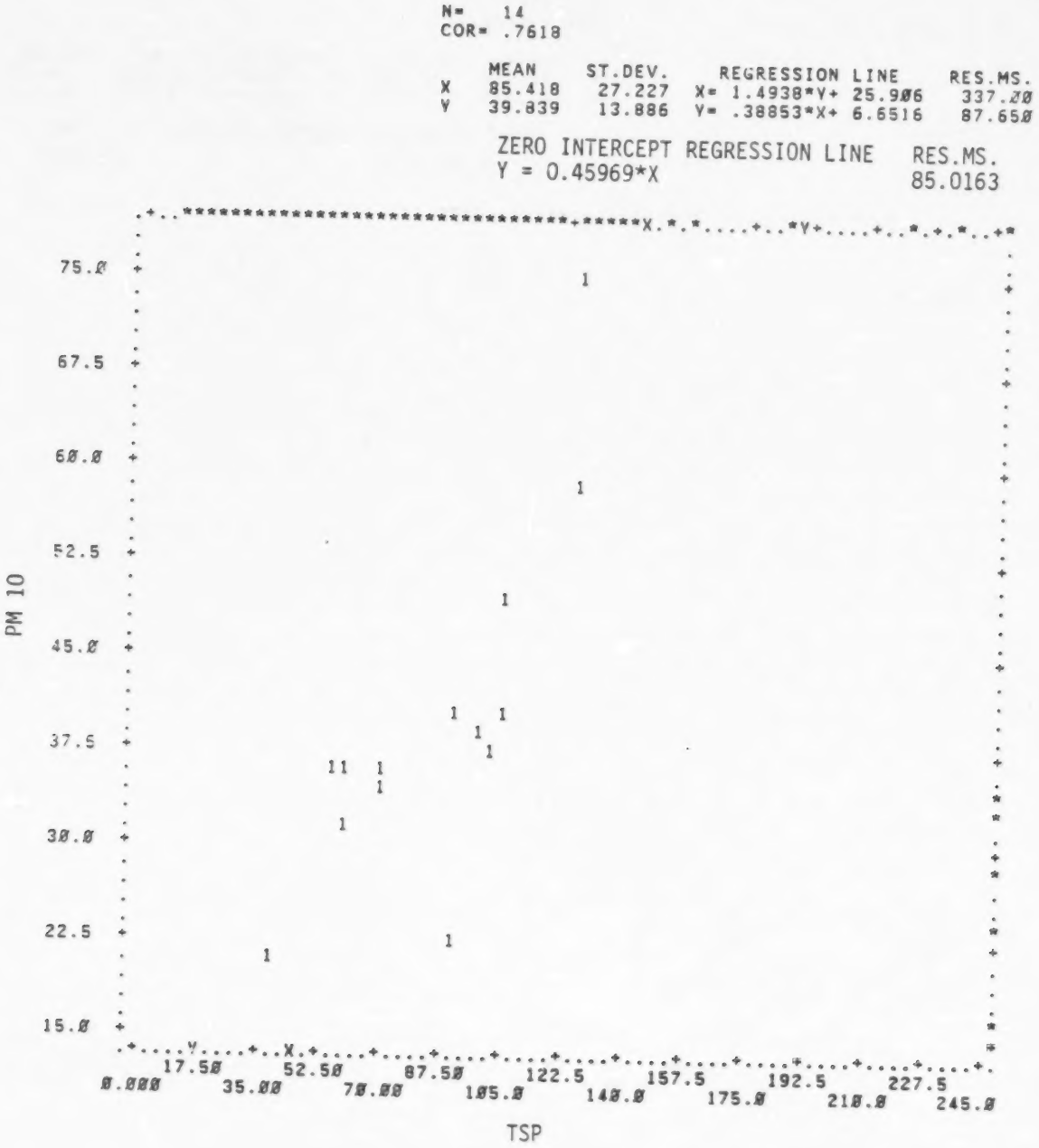


FIGURE 32b. PM 10 versus TSP.

Reproduced from
best available copy.

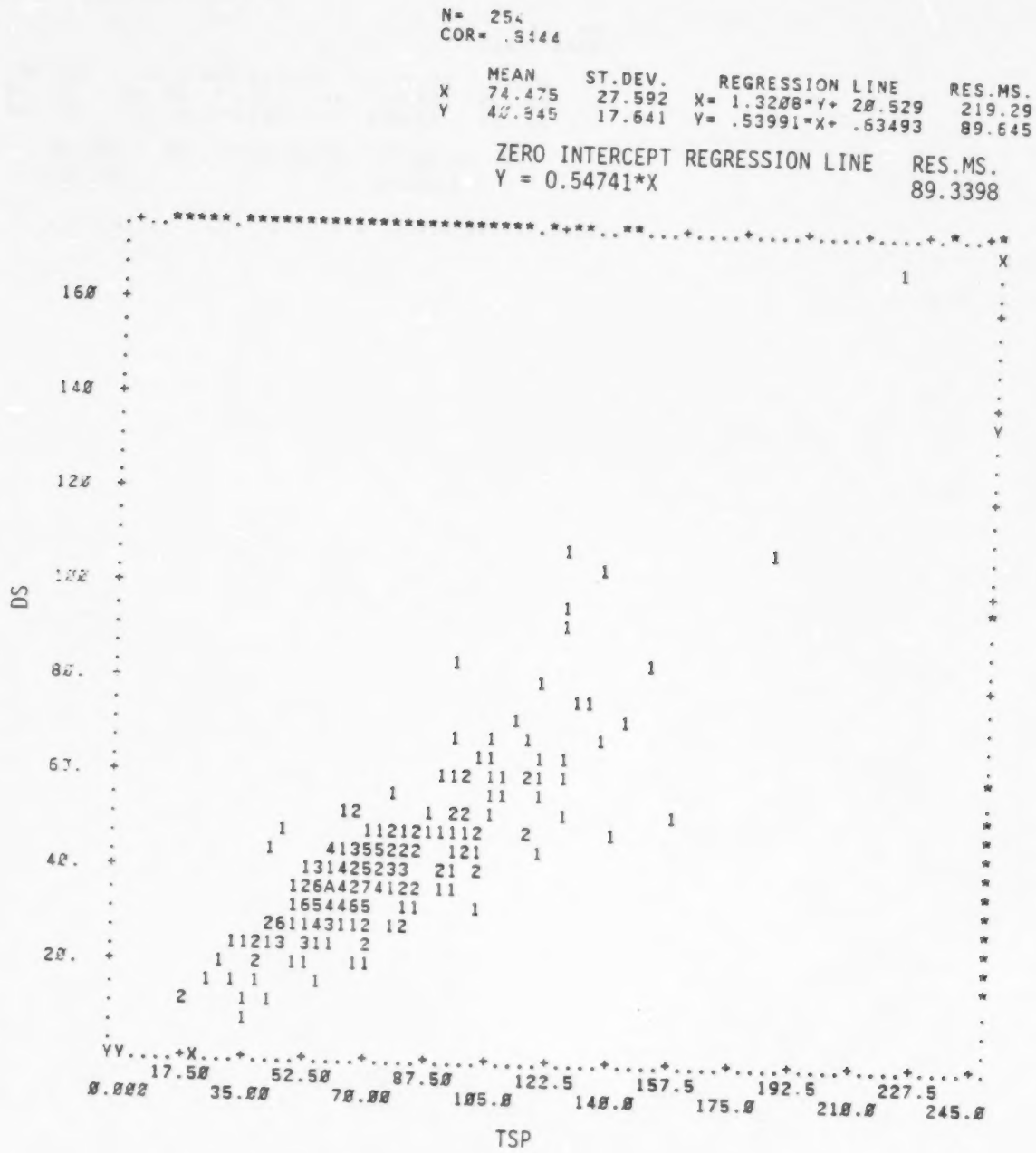


FIGURE 32c. DS versus TSP.

84003

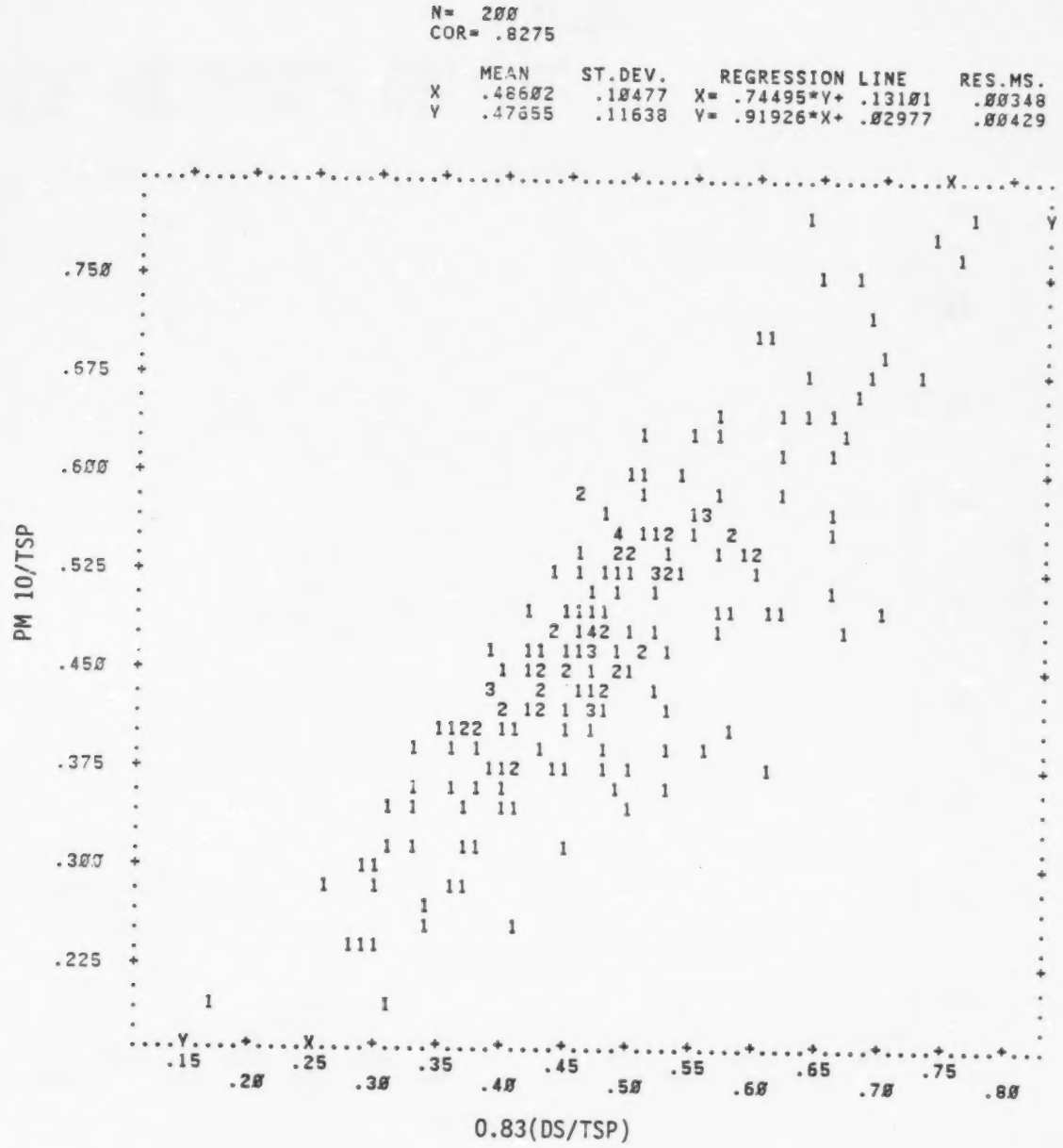


FIGURE 33. 24-hour PM 10/TSP versus 0.83(DS/TSP).

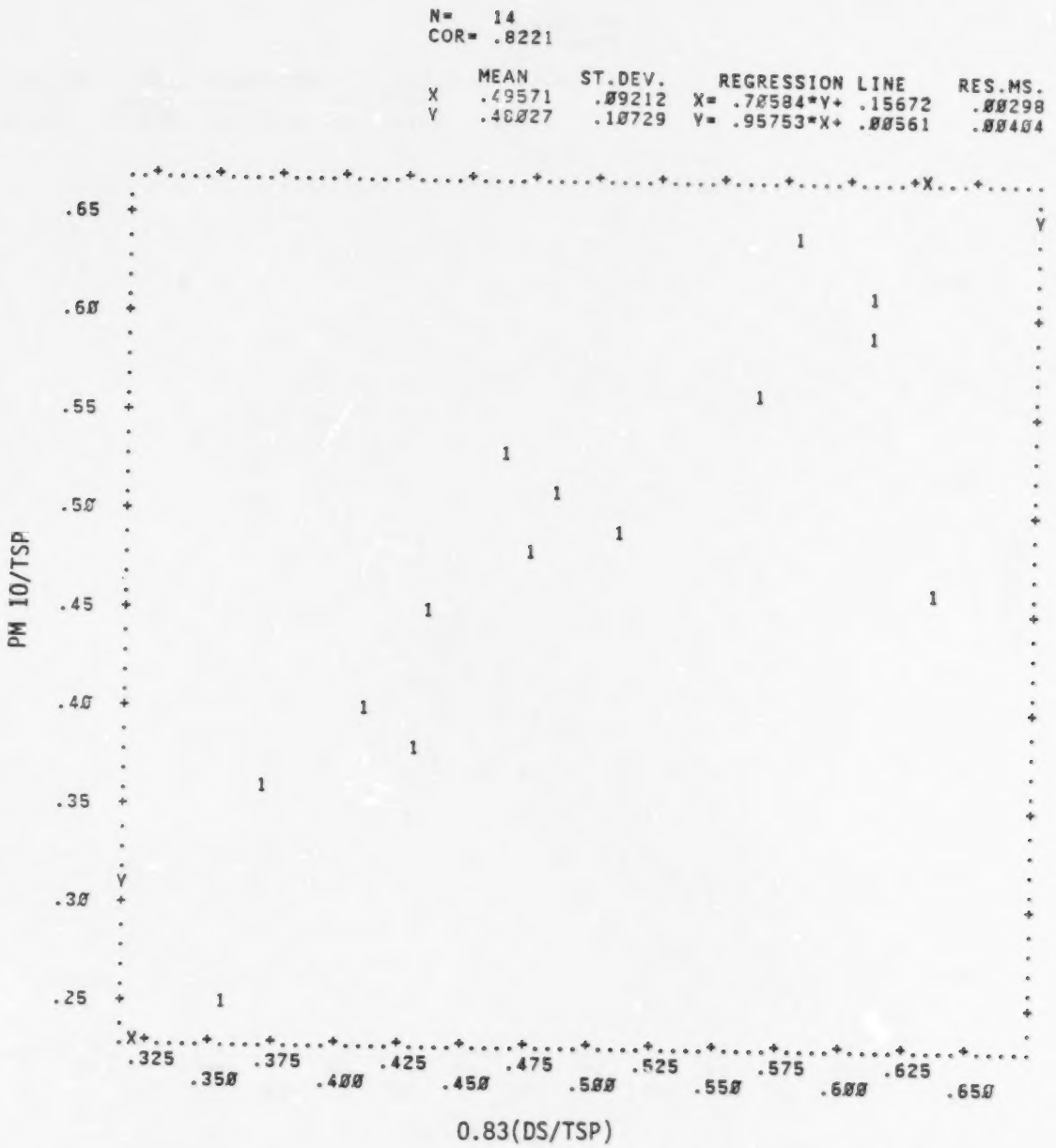


FIGURE 34. Annual PM 10/TSP versus 0.83(DS/TSP).

84003

Appendix A

SITES USED IN THE ANALYSIS

Codes are from SAROAD (Storage and Retrieval of Aerometric Data) in AEROS Manual Series, Vol. V: AEROS Manual of Codes (1976), EPA-450/2-76-005, Research Triangle Park, NC. Asterisks before names indicate a county.

010380003A07	Birmingham, Alabama
010380023A07	
010380023A57	
010380026A07	
010570001A07	Center Point, Alabama
012380029A07	Mobile, Alabama
012540001A07	Mountian Brook, Alabama
013200001A07	Tarrant City, Alabama
020040003A07	Anchorage, Alaska
030050110A07	Apache Sitegreaves National Forest, Arizona
030440006A07	*Maricopa County, Arizona
030600002A07	Phoenix, Arizona
030600002A57	
030600004A07	
030600004A57	
041440001A07	Little Rock, Arizona
050500002A07	Azusa, California
050520003A07	Bakersfield, California
051260002A07	Chico, California
052220003A07	El Cajon, California
052800005A07	Fresno, California
052820002A07	*Fresno County, California
054020002A07	Livermore, California
054020003A07	
054080002A07	Lompoc, California
054180103A07	Los Angeles, California
055760004A07	Pasadena, California
056300003A07	Richmond, California
056535001A07	Rubidoux, California
056860003A07	San Francisco, California
056980004A07	San Jose, California
060080003A07	*Arapahoe County, Colorado
060580001A07	Denver, Colorado
061260001A07	Lakewood, Colorado
061260001A57	

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061820001A07	Pueblo, Colorado
061820001A57	
062220101A07	*Weld County, Colorado
070420003A07	Hartford, Connecticut
070478001A07	*Litchfield County, Connecticut
080020001A07	Dover, Delaware
080180001A07	*New Castle County, Delaware
090020017A07	Washington, District of Columbia
090020019A07	
104360035A07	Tampa, Florida
110200001A07	Atlanta, Georgia
110200039A07	
114500017A07	Savannah, Georgia
120370004A07	Pearl City, Hawaii
130220003A07	Boise City, Idaho
141220014A07	Chicago, Illinois
141220022A07	
142360010A07	Evanston, Illinois
148320007A07	*Will County, Illinois
151520016A07	Gary, Indiana
152040021A07	Indianapolis, Indiana
152160002A07	Jeffersonville, Indiana
162500003A07	Marshalltown, Iowa
162500004A07	
171800011A07	Kansas City, Kansas
173560007A07	Topeka, Kansas
173740012A07	Wichita, Kansas
180080002A07	Ashland, Kentucky
183090001A07	Okolona, Kentucky
191490101A07	Kisatchie National Forest, Louisiana
200010001A07	Acadia National Forest, Maine
210120001A07	Baltimore, Maryland
210120008A07	
210120009A07	
211380002A07	Rockville, Maryland
211380007A07	
220240012A07	Boston, Massachusetts
220240013A07	
222160011A07	Springfield, Massachusetts
222160011A57	
222640016A07	Worcester, Massachusetts
222640016A57	
231180015A07	Detroit, Michigan
231180020A07	
241040025A07	Duluth, Minnesota
241620007A07	International Falls, Minnesota
242260049A07	Minneapolis, Minnesota
242260051A07	
243300003A07	St. Paul, Minnesota
251260003A07	Jackson, Mississippi

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260030001A07	Affton, Missouri
262380002A07	Kansas City, Missouri
262950001A07	Mark Twain National Forest, Missouri
264280007A07	St. Louis, Missouri
270160005A07	Butte - Silver Bow, Montana
270310101A07	Custer National Forest, Montana
271100020A07	*Missoula County, Montana
281880028A07	Omaha, Nebraska
290480001A07	Reno, Nevada
290580001A07	Winnemucca, Nevada
310720005A07	Camden, New Jersey
311380001A07	*Essex County, New Jersey
312320005A07	Jersey City, New Jersey
320040001A07	Albuquerque, New Mexico
320090001A07	Bayard, New Mexico
330660003A07	Buffalo, New York
330660010A07	
330660010A57	
332000003A07	*Erie County, New York
333520001A07	Lackawanna, New York
333520001A57	
334680005A07	New York City, New York
334680011A07	
334680079A07	
340700010A07	Charlotte, North Carolina
340945101A07	Croatan National Forest, North Carolina
341160006A07	Durham, North Carolina
341160006A57	
341160101A07	
341160102A07	
341160102A57	
360060014A07	Akron, Ohio
361220020A07	Cincinnati, Ohio
361300013A07	Cleveland, Ohio
361300021A07	
361300041A07	
361460001A07	Columbus, Ohio
361660014A07	Dayton, Ohio
363080010A07	Ironton, Ohio
364140002A07	Medina, Ohio
364340005A07	Middletown, Ohio
364340005A57	
366420012A07	Steubenville, Ohio
366420012A57	
367760002A07	Youngstown, Ohio
372200035A07	Oklahoma City, Oklahoma
380420111A07	*Crook County, Oregon
380500104A07	Deschutes, Oregon
380560013A07	Eugene, Oregon
381460015A07	Portland, Oregon
390100064A07	*Allegheny County, Pennsylvania
390100068A07	

390400002A07	Avalon, Pennsylvania
390780725A07	Bethlehem, Pennsylvania
390780725A57	
396620001A07	North Braddock, Pennsylvania
397140003A07	Philadelphia, Pennsylvania
397140003A57	
397140019A07	
397140020A07	
397140023A07	
397140024A07	
397140032A07	
397140036A07	
397140037A07	
397140037A57	
397140038A07	
397260021A07	Pittsburgh, Pennsylvania
410300012A07	Providence, Rhode Island
420560003A07	*Charleston County, South Carolina
440380006A07	Chattanooga, Tennessee
442540006A07	Murfreesboro, Tennessee
451310050A07	Dallas, Texas
451700002A07	El Paso, Texas
451710004A07	*El Paso County, Texas
452330024A07	*Harris County, Texas
452560034A07	Houston, Texas
454715001A07	Seabrook, Texas
460520001A07	Magna, Utah
460920001A07	Salt Lake City, Utah
470265101A07	Green Mountain National Forest, Vermont
480200020A07	*Arlington County, Virginia
481440005A07	*Hampton County, Virginia
481560002A07	Hopewell, Virginia
482140007A07	Norfolk, Virginia
482630001A07	Reston, Virginia
482660002A07	Richmond, Virginia
491840057A07	Seattle, Washington
491840057A57	
491840073A07	
492040013A07	Spokane, Washington
500280004A07	Charleston, West Virginia
502000002A07	Weirton, West Virginia
502120002A07	Wheeling, West Virginia
510240002A07	Beloit, Wisconsin
510490001A07	Chequamegon National Forest, Wisconsin
511180009A07	Green Bay, Wisconsin

Appendix B

SITE CLASSIFICATIONS ACCORDING TO CLIMATE

ARID

030050110A07	Apache Sitegreaves National Forest, Arizona
030600004A07	Phoenix, Arizona
030600004A57	
052800005A07	Fresno, California
061820001A07	Pueblo, Colorado
061820001A57	
290580001A07	Winnemucca, Nevada
451710004A07	El Paso County, Texas

WEST COAST

051260002A07	Chico, California
052220003A07	El Cajon, California
054020002A07	Livermore, California
054180103A07	Los Angeles, California

OTHER

012380029A07	Mobile, Alabama
104360035A07	Tampa, Florida
114500017A07	Savannah, Georgia
142360010A07	Evanston, Illinois
152160002A07	Jeffersonville, Indiana
173740012A07	Wichita, Kansas
211380007A07	Rockville, Maryland
222160011A07	Springfield, Massachusetts
222160011A57	
222640016A07	Worcester, Massachusetts
222640016A57	
251260003A07	Jackson, Mississippi
270160005A07	Butte - Silver Bow, Montana
270310101A07	Custer National Forest, Montana
271100020A07	Missoula County, Montana
281880028A07	Omaha, Nebraska
334680079A07	New York City, New York
367760002A07	Youngstown, Ohio
390100064A07	Allegheny County, Pennsylvania
410300012A07	Providence, Rhode Island
420560003A07	Charleston County, South Carolina
500280004A07	Charleston, West Virginia
502000002A07	Weirton, West Virginia
510240002A07	Beloit, Wisconsin

Appendix C

24-HOUR SITE CASES OMITTED BECAUSE AT LEAST ONE OF THE FOLLOWING RATIOS WAS GREATER THAN 1.05: PM 10/DS, PM 10/TSP, DS/TSP

810380023A0782 529
810380023A0782 8 3
810570001A0780 5 3
810570001A0780 5 9
810570001A0780 515
810570001A0780 521
810570001A0780 527
810570001A0780 626
810570001A0780 7 8
810570001A0780 714
810570001A0780 720
810570001A078011 17
810570001A0781 8 2
830600002A0781 6 3
830600002A0781 621
830600002A0782 312
852220003A0782 926
852820002A0780 527
856535001A0782 411
856860003A0782 821
862220101A0782 6 4
862220101A0782 616
862220101A0782 8 9
862220101A0782 926
862220101A078210 14
862220101A078210 20
862220101A078211 13
862220101A078211 19
862220101A078212 1
862220101A078212 13
862220101A078212 25
870470001A0782 628
890020017A0781 913
890020017A0781 919
890020017A078110 1
890020017A078110 13
890020017A078111 6
890020017A078111 18
130220003A078212 31
141220022A0782 616
152040021A078211 19
162500023A0782 312
162500004A0780 924
162500004A078011 11
162500004A078011 17
162500004A078012 23
200010001A0782 8 3
200010001A0782 827
210120009A078011 23
210120009A078110 7
211300007A0782 920
220240012A0780 626
220240013A0780 8 1
220240013A0781 9 7

242260051A078012 5
260030001A0780 931
290580001A0780 7 2
310720005A0782 8 3
311380001A0781 329
311380001A078112 30
311380001A0782 228
311380001A0782 4 5
311380001A0782 8 3
320640001A0782 216
320090001A078012 17
320090001A0781 4 4
320090001A0781 8 8
320090001A0781 820
320090001A0781 9 7
330660003A078010 6
330660003A078011 11
330660003A078012 5
330660003A0781 1 4
330660003A0781 122
330660003A0781 2 3
330660010A078212 31
332000003A0780 8 7
332000003A0780 813
332000003A0780 819
332000003A0780 825
332000003A0780 831
332000003A0780 9 6
332000003A0780 918
332000003A0780 930
332000003A078010 6
332000003A078010 12
332000003A078010 24
332000003A078011 5
332000003A078011 11
332000003A078011 17
332000003A078011 23
332000003A078012 11
332000003A078012 23
332000003A0781 221
333520001A0781 522
334680005A0781 9 7
334680079A0781 9 7
340780010A078211 13
340780010A078212 1
340780010A078212 7
340780010A078212 13
340780010A078212 19
340780010A078212 31
341160006A078212 1
341160101A0780 7 2
341160102A0781 919
341160102A0781 925
341160102A0782 4 5

361300013A0781 826
361300021A0780 7 8
363080010A078111 12
363080010A0782 2 4
366420012A0782 5 5
366420012A0782 8 3
366420012A078212 19
367760002A078212 7
367760002A078212 25
380500104A0780 415
380500104A0780 5 9
380500104A0780 521
380500104A078011 29
380560013A0780 9 6
380560013A0780 918
381460015A0780 4 3
381460015A0780 415
381460015A0780 427
381460015A0780 620
390780725A0782 210
396620001A0782 210
396620001A0782 3 6
396620001A0782 5 5
396620001A0782 722
397140003A0782 722
397140003A078211 25
397140003A5782 3 6
397140003A5782 716
397260021A0782 7 4
397260021A0782 716
451700002A0780 421
451700002A0780 614
454715001A0781 8 2
460520001A0781 721
460520001A0782 1 5
481560002A0781 416
491840057A078212 31
491840073A0780 4 9
492040013A0782 7 4
510240002A0782 216
511180009A0782 4 5

Appendix D

ANNUAL SITE CASES OMITTED BECAUSE AT LEAST ONE OF THE FOLLOWING ANNUAL RATIOS WAS GREATER THAN 1.05: PM 10/DS, PM 10/TSP, DS/TSP

332000003A0781
050520003A0782
052800005A0782
061820001A0782
062220101A0782
130220003A0782
290480001A0782
381460015A0782
460520001A0782
460920001A0782